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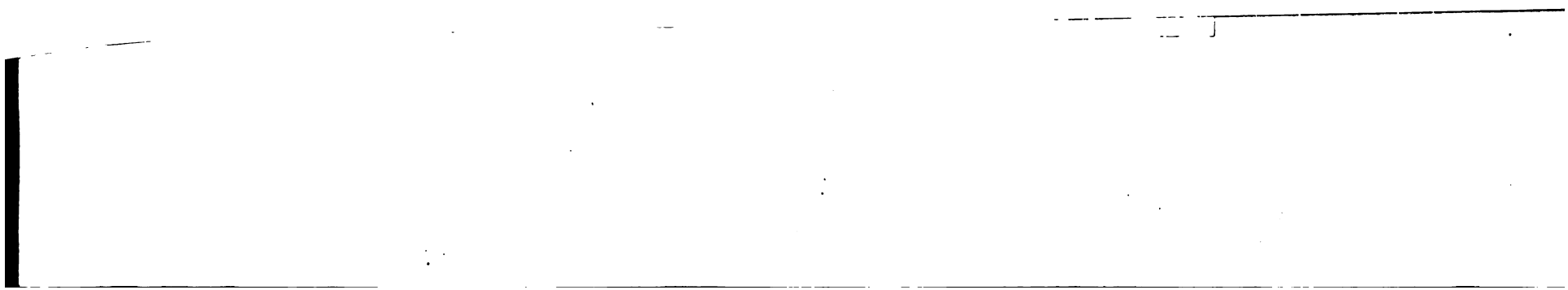

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS AND HISTORY.

GEOLOGICAL SURVEY OF TEXAS

JNO. F. HOLLINSWORTH, Commissioner. E. T. DUMBLE, State Geologist.

REPORT

ON THE

BROWN COAL AND LIGNITE

OF

TEXAS.

CHARACTER, FORMATION, OCCURRENCE, AND FUEL USES.

BY

EDWIN T. DUMBLE, F. G. S. A.,

STATE GEOLOGIST.

AUSTIN:

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11 Sept, 1893,
Dr. David A. Greene
Boston.

LETTER OF TRANSMITTAL.

OFFICE OF COMMISSIONER OF AGRICULTURE,
INSURANCE, STATISTICS, AND HISTORY,
AUSTIN, TEXAS, December 12, 1892.

Hon. James S. Hogg, Governor of Texas:

DEAR SIR: I have the honor to submit herewith the Report on the Brown Coal and Lignites of Texas, as prepared by the Geological Division of this department.

State Geologist E. T. Dumble visited Germany and Austria and made a careful and thorough examination of the mines and factories of those countries to ascertain the character, use, and value of lignites, and by comparison to find out the value of the lignites of Texas, and how same could be best utilized as fuel.

The question of cheap fuel, especially for manufacturing purposes, has long been a serious one with Texas, which has been solved by Professor Dumble, as will appear from the results of his efforts embraced in this Report, for which he deserves great praise. The last few months, including the trip to the other side, has been only a small portion of the time he has given to the utilization of Texas lignites, for it has been a study of years with him, and long before his connection with the State Survey he became interested in the subject and devoted much time and attention to it. The result at last achieved has fully repaid him for all work done. Texas will reap the grand benefits, for the capitalists will come and establish industries, the wants of the people will be supplied at home, and prosperity will abound.

That the brown coal is the cheap fuel so long needed is no longer a question, for which all Texas should rejoice.

I am, with much respect and esteem, your obedient servant,

JNO. E. HOLLINGSWORTH,
Commissioner.

LETTER OF TRANSMITTAL.

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTIC, AND HISTORY,
GEOLOGICAL SURVEY OF TEXAS,
AUSTIN, TEXAS, November 1, 1892.

Hon. J. E. Hollingsworth, Commissioner of Agriculture, Insurance, Statistics, and History, Austin, Texas:

DEAR SIR: I have the honor to transmit herewith my Report on the Brown Coal and Lignite of Texas, embodying the results of my investigations so far as I have been able to complete them.

The scope of the investigation might have taken a much wider range, but practical results were wanted, and I have therefore confined myself in this Report to the character, formation, occurrence, and fuel uses of brown coal and lignite.

As this character of fuel has not formed the subject of such detailed investigation in this country as it has in Europe, any description of the coal or its utilization must draw most largely from foreign sources, as it is only there that machinery and appliances can be found especially designed for its use, the adaptability of which have been proved by actual trial.

While a part of the material used has been derived from the excellent literature on this subject by German, French, and Italian authors—and I have endeavored to bring together the facts which bear on the subject by liberal quotations from the different authorities—it is also true that a large part of it was secured by my personal observations and investigations among the mines and factories of Germany and Austria, and some of the most practical portions of the work could not have been obtained in any other manner.

I have also endeavored to bring together as clearly as possible the general statements regarding the geology and the details of the occurrence of the Texas deposits, in order that they might be the more readily accessible to those who may wish to use the Report.

In conclusion, I beg that you will accept my sincerest thanks for the constant support and encouragement which you have so kindly afforded me during the progress of the work.

Yours, very truly,

E. T. DUMBLE,
State Geologist.

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BROWN COAL AND LIGNITE.

BY E. T. DUMBLE.

CHAPTER I.

INTRODUCTORY AND HISTORICAL.

The question of a fuel supply adequate for all purposes has a most important bearing on the development of a country. During the earlier stages of its history wood, when sufficiently abundant, answers for fuel, but with increased population and consequent demand for manufactures comes the necessity for a better combustible, such as is found among the fossil fuels stored up by natural agencies during the evolution of the earth.

These fossil fuels occur at many different horizons, but those of the Carboniferous or coal period proper are, taken as a whole, the best adapted for all purposes because they combine compactness with large proportionate heating power and ability to withstand transportation without serious loss. In many places, however, where coal deposits of this age are missing, others are found of more recent formation, which, under proper conditions, will more or less completely supply the lack.

Such is the case in Texas. The aggregate area which is underlaid by beds of fossil fuel is very large. In the northern central portion of the State the coals of the Carboniferous or Coal Measures occupy an area of several thousand square miles. In this area there are nine distinct seams of coal, two of which are of workable thickness and of good quality.* A second, but as yet unexplored, basin of similar age occurs on the Rio Grande border in Presidio county. These are, however, somewhat distant from many localities at which are found ores and materials which would afford bases for great industrial development with proper fuel supply.

In the vicinity of Eagle Pass, on the Rio Grande, there is a third basin

*Second Annual Report Geological Survey of Texas, p. 359, *et seq.*

containing a vein of good coal in beds which belong to the upper part of the Cretaceous formation.*

By far the most extensive beds, however, are those occurring in the Tertiary area, which stretches entirely across the State from Red River to the Rio Grande,† and in which the coal beds frequently show a thickness of ten to fourteen feet in a single bank, with a total thickness in certain localities of from eighteen to twenty-four feet. These constitute, therefore, the greatest and most widespread fuel supply which is found in the State, and the desirability of utilizing these deposits for manufacturing and domestic purposes has naturally suggested an examination into the possibility of doing so.

The existence of lignite or coal, as it was usually denominated, has been recognized in Texas almost from the time of its first settlement by Americans. In many of the early books and papers descriptive of Texas the occurrence of this coal is mentioned and localities given.

In an article entitled "Observations on the Geology of Trinity county, Texas," by J. L. Riddell, M. D., published in the American Journal of Science and Arts, Vol. XXXVII., No. 2, 1839, pp. 216-217, I find the first definite description of the Texas brown coal, as follows:

* * * "In the banks of the Trinity, associated with the iron ore, and overlying the brown coal, whole trees and fragments of trees, piled sometimes one upon another, present themselves completely transformed into stone. In some logs a diversified metamorphosis is observable; one portion of the vegetable structure having been replaced with silex, another with brown oxide of iron, and a third is bitumenized or converted into coal.

"In concert with Dr. F. B. Page, I took considerable pains in the exploration of the Trinity brown coal formation. As no excavations for working have yet been made, the best places for inspecting the formation are where the Trinity cuts its way through the highlands, or where its banks present themselves in bold high bluffs, as at New Cincinnati, and near the site of the projected town of Osceola. The coal lies in horizontal strata, dipping one foot in thirty to the northwest. The main stratum at the latter place, just above Bedias creek, is repre-

* First Report of Progress Geological Survey of Texas.
First Annual Report of the Geological Survey of Texas.
Notes on the Geology of the Valley of the Middle Rio Grande, E. T. Dumble.
† First Report of Progress Geological Survey of Texas.
First Annual Report Geological Survey of Texas.
Second Annual Report Geological Survey of Texas.
Utilization of Lignites, E. T. Dumble.

sented by the concurrent statement of W. C. Brookfield, surveyor, Mr. James S. Hunter, of Huntsville, Texas, Dr. Page, and some other persons whom I consulted, as between six and seven feet in thickness, the lower portion being between three and four feet above low water mark. Unfortunately, during my sojourn there, the river was unusually high and turbid for the season of year; I could not consequently verify the same by personal observation and measurements. The most considerable coal beds which I had opportunity fully to inspect, were in the Trinity bluffs, southwest side, at New Cincinnati, six miles lower down, and just below the mouth of Salt creek, near six miles above. The workable stratum of brown coal in each of these localities is about five feet thick, and situated some fifteen feet or so above low water mark. In quality it is said to be precisely similar to the coal in the seven feet bed.

"Specimens of average quality, which I took from the bed near the mouth of Salt creek, have a specific gravity of 1.326. The proportion of carbon or coke is forty-seven parts in one hundred (47-100). The volatile portion consists of bitumen, creosote, pyroligneous acid and water. Upon burning one hundred parts of the coal, there remains a trifle more than one part by weight of white ashes. The color of this coal is a dark umber brown, nearly black. Its ligniform structure is almost always easily discernible. It is readily ignited, burns with a pleasant flame, and with almost the same facility as charcoal. Although it has much less bitumen in its composition than the Pittsburgh or cannel coal, it will yet prove valuable for nearly all purposes for which coal is applied; such as parlor use, the reduction of ore, and the generation of steam power. It is, however, ill adapted for the manufacture of inflammable gas.

"This sort of coal is denominated *brown coal* or *brown lignite* by mineralogists. Sometimes it is called Bovey coal, because a thick bed of it has long been wrought at Bovey, near Exeter, in England. It occurs in many parts of the world, in some places in vast abundance, but generally in beds of far less extent than those of the Trinity. It is worthy of remark that iron pyrites, generally so abundant and detrimental in coal, is here usually scarce."

Dr. Francis Moore, Jr., in "Description of Texas," published in 1840, mentions the following localities:

"A large bed of lignite is found in the banks of the Colorado a few miles above La Grange."

"In the banks of the Brazos and Little Brazos are immense beds of coal or lignite."

"An extensive bed of excellent coal has been found in the Yegua, about twelve miles from the town of Independence, Washington county."

W. Kennedy, in his work entitled "Texas," published in 1841, speaks of the coal on the Trinity.

In 1848 C. S. Hale published "Geology of South Alabama," in the American Journal of Science and Arts, which contains the following statement in regard to lignite:

"It is found also at Natchitoches, on Red River, where the underlying bed consists of a gray plastic clay, very adhesive; on Bedias creek, near the Trinity river, Texas; at Robbin's Ferry, on the Brazos; and at Bastrop, on the Colorado." Page 356.

In "Texas in 1850," Melinda Rankin says:

"Bituminous coal is also found in different parts of the Trinity river, both above and below Magnolia, and has been in use some time for various purposes."

Other similar announcements of the existence of these beds were made during these years and those which followed previous to the organization of the first Geological Survey under Shumard. In 1857, lignite was announced from Burleson county, and also from Gonzales. In 1858, J. De Cordova, in "Texas, Her Resources and Her Public Men," mentions the coal of Guadalupe and Bastrop counties.

The surveys under Shumard and Buckley both described many new localities, and in a general way marked out the entire area in which they occur.

Many efforts have been made to utilize the brown coal deposits, and small workings have been begun in many places. In some localities these have been carried on in a desultory manner for a year, or even longer, but in the end they have one after another been deserted, until to-day there are only a few localities at which lignite is being mined for use. The principal ones among these are:

San Tomas Mine, Webb county.

Lytle Mine, Medina county.

Kirkwood Mine, Atascosa county.

Alba Mine, Wood county.

Henderson Mine, Rusk county.

Rockdale Mines, Milam county.

Calvert Bluff, Robertson county.

McDade Mine, Bastrop county.

The reasons for the failure of the efforts to bring lignite into general use have been of various kinds. In many places the cheapness of wood

has prevented the use of any other fuel. Even in localities in which the lignite is abundant and easily mined, wood has been easier to get and is therefore used for all household purposes and in steam making. The stoves and furnaces in use are adapted either for wood or bituminous coal, and do not give favorable results with lignite. Lignite usually contains considerable hydroscopic water, and on exposure to the air the evaporation of a portion of this causes it to slack and form a large amount of small coal. This occurs also in the fire box at times, and as the grates are not arranged for such fuel, that which slacks in the yard can not be used, and much that slacks in the furnaces falls unburned through the grate bars into the ash pit. Another source of loss in burning, due largely to the same property of crumbling, is the large amount unburned carried off by the draught.

Another reason why it has not been brought into use is that those who understood its nature, and could and did use it successfully, could not depend on getting a proper supply at suitable figures. This in turn was due, in part at least, to the fact that the number of such consumers was too small to warrant mining on a large scale, and the amount of the traffic was not great enough to secure from the railroads the low rates of freight necessary to properly introduce it.

Many experiments have been made in burning lignite, both under stationary boilers and in locomotives, but I do not know of a single instance in which there was any fire box tried other than those in ordinary use for burning wood or coal under the same engines. The results of these experiments have varied according to the conditions under which they were made. Where the person in charge recognized the character of the fuel with which he had to deal, and used it accordingly, the results have been highly favorable in every instance, even with the drawbacks of a fire box not suited to it. Among such experiments may be mentioned the mills and gin at Bastrop, experiments by J. A. Cushman at Houston, the experiment of the International and Great Northern Railway with Rockdale lignite, the long continued test of the mills at Corsicana, and many others, as well as its actual use at present in considerable quantities in San Antonio, at Rockdale, Austin, Waco, and Dallas.

In the spring of 1877, at the request of Mr. A. S. Richardson, then secretary of the Houston and Texas Central Railway, I took up the study

of lignites with a view to their preparation in some way as fuel for use in their locomotives. Being practically without library facilities, the whole question naturally resolved itself into one of actual experiment, with the result that I found a fair coke could be made by adding a small percentage of coal tar pitch and burning in a tightly covered crucible at high temperature. I also tried many other substances as cementing material, such as common molasses, sugar, caking coal, etc., which gave variable results, sometimes yielding a coherent coke, at others simply the usual powdery coke of the lignite itself. The best results were obtained by introducing the extraneous substances first and covering them with the lignite. When they were mixed through the body of lignite, the results were not always so favorable. The coke made in this manner was of fair quality, and arrangements were made for the erection of a trial oven for carrying on the experiments on a scale large enough to prove its actual value and ascertain approximately the cost of production. The completion of this was prevented by circumstances beyond my control.

In the meantime, my attention was called to the experiments made by E. F. Loisseau in briquetting anthracite waste in Pennsylvania, and the briquetting works at Rondout, New York, and I made an effort to have a test made of the briquetting of Texas lignites at one of these places.

Not succeeding in this, I finally made arrangements, through Mr. Robert Grimshaw, of Philadelphia, to have a test made of the briquetting properties of Texas lignites by the Société Nouvelle des Forges et Chantiers de la Méditerranée, at Havre, France. In accordance with this arrangement, ten tons of lignite, taken from the bank exposed on the Brazos river a few miles west of Calvert, were forwarded to Havre, in August, 1881. Their report on it was to the effect that the machines manufactured by them would make a compact fuel of lignite such as that sent, but that its calorific value was not as great as that of the briquettes they were then making from their bituminous coal. As will be seen from the analysis of the lignite sent them, it was far below the usual average.

ANALYSIS OF LIGNITE BRIQUETTED BY THE SOCIÉTÉ NOUVELLE DES FORGES ET CHANTIERS DE LA MÉDITERRANÉE, OCTOBER, 1881.

Water	20.30
Volatile matter	35.94
Fixed carbon	31.56
Ash	12.20

An effort was made at the time to establish manufactories for the production of this character of fuel, and contracts were prepared, but owing to business changes and depression they were not carried out.

During the same year, 1881, several letters appeared in the papers of the State, calling attention to this method of utilizing lignite, and in 1882 Prof. H. H. Dinwiddie, then president of the Agricultural and Mechanical College of Texas, recommended its use by conversion into water gas. I also published a leaflet on the subject of utilizing these brown coals, the main portion of which has been reprinted in the chapter on this subject in the Reports on the Iron Ore Districts of East Texas.* In 1888 Prof. Streeruwitz published two articles on this subject in the Geological and Scientific Bulletin, recommending especially the use of the "Treppenrost" or step-grate.

Other efforts were made from time to time to introduce briquetting machines, but always without success, owing to the lack of authentic detailed information regarding them in this country. That which came nearest succeeding was made by the Austin Coal Company, which owned works at Rockdale. This company bought a press in Europe and brought it as far as New York, but financial difficulties overtook them and they were unable to carry out their plans.

Such was the position of affairs at the beginning of the work of the Survey, and as our analyses of lignite from various portions of the State continued to prove their excellent quality, the question of their utilization gradually took shape, and finally culminated in an appropriation by the Legislature for an examination of the possibility of such use.

Under this Act of the Legislature, and in accordance with the instructions of the Commissioner of Agriculture, Insurance, Statistics and History, I visited the principal deposits of brown coal in Germany and Austria, compared the different varieties with those of Texas, and examined the various methods of utilizing them.

Throughout my entire trip I met with the kindest attention and with the most ready and valuable assistance from the geologists and mining

*Second Annual Report Geological Survey of Texas, pp. 57, *et seq.*

This chapter is a compilation by Mr. Lerch from Dr. Wagner's "Jahres-Bericht über die Leistungen der Chemischen Technologie," and from the different publications of the survey. It gives in a general way the methods of utilization of brown coal in Europe, and some of the facts regarding the occurrence and quality of the Texas deposits.

officers, both public and private; and it was only through the opportunities thus afforded that I was enabled to gather the necessary information.

ACKNOWLEDGMENTS.

I am under special obligations for assistance and courtesies to Dr. Hauchecorne, Director of the Geological Survey of Germany, and to other members of the survey; to Frhr von der Heyden-Rynsch, Imperial Director of Mines of the District of Halle a. S.; Dr. Brassert, Imperial Director of Mines of the District of Bonn; Prof. H. Credner, University of Leipzig; Prof. Frech, University of Halle; Prof. Laube, German University of Prague; Eng. E. Preissig, Prague; Dr. Geinitz, Director of the Royal Mineralogical Museum, Dresden; Profs. Toula, Oser and Hofrath von Hauffe, Institute of Technology, Vienna; Profs. Höfer and Kupelwieser, Mining Academy, Leoben; Alex. von Napolski, Halle a. S.; the officers of the A. Riebecksche Montan-Aktién-Gesellschaft, Halle a. S.; Oesterreichisch-Alpine Montangesellschaft; Teplitzer Walzwerk und Bessemerhütte; Wiener Locomotivs-Fabrik; Zeitzer Eisengiesserie und Maschinenbau Aktién-Gesellschaft; and above all to Prof. Freiherr von Fritsch, of the University of Halle.

CHAPTER II.

BROWN COAL.—ITS ORIGIN, FORMATION, PHYSICAL AND CHEMICAL CHARACTER.

Various classifications of the coals have been proposed by different authors, but none have come into general use, or taken the place of that which is based upon their geological age, which is this:

Name.	Geological age.
Peat	Recent and Quaternary.
Brown coal and lignite	Tertiary to Triassic.
Coal, or stone coal	Carboniferous and older.

The coal of the Coal Measures in Texas is of the bituminous variety, of the same general character as the coal of the Indian Territory, and much of it yields a fair quality of coke when burned in ovens.

According to the classification given above, the coal of our Cretaceous area belongs under the head of brown coal, and it is true that in a few places small quantities of lignitic coal are found among the beds of this age. This occurs principally in the sands of the Bosque and Red River divisions, but nowhere, so far as yet determined, in workable quantities. The greater part of the coal of this age, as it is developed in the vicinity of Eagle Pass, resembles the bituminous coal of the Carboniferous much more closely in every characteristic than it does any of the varieties found in the Tertiary. In addition to this, certain portions of this bed yield a good coke in the crucible in the laboratory, and thereby give promise, at least, of coking on a larger scale.

When we come to a critical study of the deposits of the Tertiary, we find that the varieties of brown coal occurring in them are numerous, and correspond closely with those recognized in Europe, including true lignites and lignitic coals. Therefore, while it has been customary in this country to use the term Lignite as synonomous with brown coal, and to apply the term to deposits of Secondary as well as Tertiary age, I have concluded, on account of the marked dissimilarity of the coals of these periods, as they occur here, to adopt the definition and classification of Zincken for the purposes of this report, and to include under the general

name of brown coal "those fossil accumulations of the more or less carbonized remains of plants which occur in the Tertiary formation."

Under this classification "Lignite" is made the name of a variety of brown coal, and is not used as a generic term.

Brown coal, whether considered physically or chemically, may be justly regarded as a substance intermediate between peat on the one hand and bituminous coal on the other. There is no hard and fast line of division between these substances, but each grades into the other by such small differences that it can not be said where one ends and the other begins.* Indeed, so closely do certain varieties of each simulate the other, that there is no test which can decide between them as to which is bituminous coal and which is brown coal, and the determination can only be made by their geological relations.

Zincken says of this:

"There are no physical or chemical qualities by means of which a coal may in every instance be characterized as a brown coal and distinguished from the other species of coal. Coals of different formations are in their external character similarly variable. At Malowka, in Russia, a Carboniferous coal has been found, which possesses altogether the appearance of a brown coal, and one of the more recent ones at that. The fact of its relative position as belonging to the Carboniferous formation, was first determined only after careful scientific investigation. There are Cretaceous coals which appear to be identical with certain kinds of brown coal, and alluvial coals, even peat itself, are met with, which closely resemble varieties of stone coal. Hence, the only certain method of determining the relative age of a coal is by the geological and paleontological conditions of its occurrence." †

ORIGIN.

The fossil fuels are mainly of vegetable origin, and their differences are principally due to the character of the vegetation from which they

*"Brown coal or lignite contains 20–30 per cent of oxygen after the expulsion at 100 degrees C. of 15–36 per cent of water [as against "5–15 per cent (rarely 16–17) of oxygen, ash excluded," in ordinary bituminous coal]. The hydrogen in each is 4–7 per cent. Both have usually a bright pitchy luster (whence often called *Pechkohle* in German), a firm, compact texture, are rather fragile compared with anthracite, and have a specific gravity from 1.14 to 1.40. The *brown* coals have often a brownish-black color, whence the name, and more oxygen, but in these respects and others they shade into ordinary bituminous coals." —Dana, J. D., System of Mineralogy, 1892, p. 1021.

† Zincken, C. F. Die Physiographie der Braunkohle, Leipzig, 1867, p. 5.

were derived and its condition at the time of deposit; the manner and place of its deposition; the character, completeness or incompleteness of the chemical changes which have since taken place in it; and the changes induced by earth movements, pressure of superimposed beds, etc.

That all are alike of vegetable origin, is proved by the occurrence of portions of plants, often carbonized, throughout the coal beds, the presence of their roots in the under clay, and by the woody structure of the body of the coal itself, which is often clearly discernible in thin sections under the microscope.

The vegetable matter from which coal is derived consists of:

Trees, shrubs and herbaceous vegetation of lacustrine and dry land growth.

Peat bog vegetation.

Marine plants.

While coal occurs in older formations, the first great accumulation is found in the Carboniferous period. The plant life of this period, as we find it recorded in the great number and variety of forms preserved as fossils in the coal and under clay, the overlying sands and in the shales of the formation, was of three kinds. The first of these were conifers, which grew on the higher lands, and only furnished such part of the material for the formation of coal as was carried down into the coal swamps by freshets. Their remains are usually found in the sands which overlie the beds of coal. There were numerous species of these trees, which have their nearest representatives at present in the Yew and Japanese Ginko. Another class of plants, the number of species of which was fully one-half of all the flora of that period, were the ferns. Like the conifers, the material which they furnished for conversion into coal was inconsiderable when compared with that of the plants of the third class, but they had their use as they "formed the thick underbrush of the coal swamps." Many of the ferns of that time closely resemble those of to-day in size and form, but there were also many varieties of tree ferns such as now grow only in warm latitudes.

"Coal consists," says Bischoff, "chiefly of the stems of Stigmaria, Sigillaria, Lepidodendra, and Calamites." These Stigmaria, Sigillaria and Lepidodendra were a character of plant growth intermediate between the conifers and the club-mosses. They were composed of "a dense outer bark or rind, inclosing a great mass of cellular tissues, through the

center of which runs a small fibro-vascular cylinder with very distinct pith." They formed trees forty to one hundred feet in height, with wide-spreading roots and gently tapering trunks, which were covered with scale-like or needle-like leaves, the characteristic cicatrices of which may often be recognized where the bark is sufficiently well preserved. The Calamites much resemble the horse-tails (*equisetaceæ*) existing to-day, except that in size they were very much larger, forming trees having a diameter of six inches and a height of thirty feet or more. All were marsh plants, and flourished best in an atmosphere warm and moist, and "stifling" from the amount of carbonic acid in it.

With the advent of the Cretaceous period and a larger land area, land plants began to furnish a greater proportion of the material for the coal beds. Dicotyledonous trees appeared at this time, and have ever since continued to increase in importance.

The conditions of plant life inaugurated in the Cretaceous continued with gradual increase into the Tertiary, and in this period the vegetable matter derived from forest growth first took its place as a great factor in the production of coal. Material derived from such forest growth, however, did not supply all the material for the production of the brown coal of the Tertiary. Even at present, when the Dicotyledons represent so large a portion of the plant life of the globe, they furnish only a portion of the material which is passing into coal through the media of peat bogs, submerged forests, rafts, delta and other deposits. Another source of supply has always existed in the growth of *Sphagna* and similar plants which have played an important part in coal production from the earliest times to the present. These plants, like those which formed the coal, are of swamp growth and form the peat bogs of the present time.

The part taken by marine plants in furnishing material for coal deposits does not seem to be clearly defined. So far as they are composed of hydrocarbons there is the possibility of their alteration to coal, just as there is of animal life contributing to the same end, and doubtless such alterations have taken place in both cases.

The differences directly traceable to the character of the vegetation from which the coals have been derived is shown in the conditions found in peat bogs, as described by Lesquereux:

"In Sweden and Denmark peat deposits, rarely of wide extent, but sometimes very deep, are of frequent occurrence. The soil is undulat-

ing and diversified, with a great number of large ponds or small lakes, which have been filled by a growth of peat. At Waldmarsland, near Copenhagen, I had the opportunity of examining the separate layers and the composition of one of these peat deposits, which in that country are considered mines of wood.

"At the bottom, that is the lowest level reached by the drainage, lay four feet of black, compact peat, and over it a stratum of prostrated trees (pines), most of them laid in the direction of the slope of the basin, the tops of the trees pointing toward the center. The trunks of a large number of these trees measured from six to ten inches in diameter. They still kept their branches imbedded in a mass of leaves and cones, and even mushrooms. According to the proprietor of the mine, this lower stratum of peat and prostrated forest had a total thickness of eight feet.

"It was overlaid by a bed of black peat four feet thick, covered in its turn, like the other, by a bed of prostrated trees (birches, *Betula alba*,) three feet thick.

"Above that again was a third bed of peat, six feet thick, less compact than the two beneath it, and of a yellowish color, but covered in the same manner by a stratum of large trunks of oaks, some of them two or three feet in diameter, their wood being still in so perfectly sound a state of preservation that they could be cut and sawed for timber.

"Over the oaks there was a fourth bed of fibrous yellow peat, three feet eight inches thick, made up mostly of mosses not yet fully decomposed.

"The total thickness of these deposits, so far as mining operations exposed it, was thirty feet; but the proprietor, one of the best informed land owners in the country, informed me that both his own deposit and others in that region were known to be at least twice as deep, but were never worked to the bottom on account of the difficulty and cost of draining them."*

Here we have the marsh vegetation, the mosses, passing directly into peat by cumulative resolution—just as was the case with the swamp vegetation of the Coal Measures—while the woody plants of the submerged forests grown *in situ* have preserved their original structure, and are being converted into lignite. That this is the usual form of alteration is supported by many examples given by the same author and others. The observations of others show us that even when this cumulative resolution has gone on in such plants as Lepidodendra, Sigillaria, etc., until all trace of the interior structure of the plant is destroyed, the external form is still recognizable in beds of otherwise homogeneous coal.

Where, however, the woody matter entering into the formation of

* Origin of Coal, Geological Survey Pennsylvania, 1885, pp. 109, 110.

coal comes to its place of deposit in a more or less finely divided condition, lignite is not formed, but the material simply takes its place in the deposit, with which it alters to peat, brown coal, etc. Such material is derived from mouldering of the leaves, stems, branches, or fallen trunks of trees carried from the place of original growth by floods, or even from the disintegration of lignitized material itself by similar agency, or passing directly into deposits at the place of growth, as is sometimes the case in emerged bogs.

The character of the coal, therefore, depends somewhat upon the degree of maceration which plants undergo before final deposition.

A difference which may be traced to the manner of its deposition is found in the earthy brown coals of the Province of Saxony, with their "schweelkohle," and the other brown coals in which this latter is missing.

Prof. von Fritsch has shown that resinous trees were largely instrumental in furnishing the materials of the brown coal deposits with pyropissite in the vicinity of Halle an der Saale. In a paper read before the meeting of the IV. Allgemeinen Deutsche Bergmanstag in Halle a S., September, 1889, he describes his investigations into the nature and composition of the brown coal and pyropissite.* Pyropissite, or tar coal, is not a coal at all, in the real signification of that term, but belongs to a different class of hydrocarbons. Pyropissite melts, while brown coal burns without melting; and there is also a great difference in the specific gravity of the two, pyropissite being lighter than water, ordinarily sp. gr. 0.9, while brown coal ranges from sp. gr. 1.2 to 1.4, and often higher. In his investigation he found, after digesting brown coal with fuming nitric acid for a day or two, that it was brought into a solution having a brown color, in which swam numerous organic particles. These were purified with water, and afterwards with alcohol, and proved to consist of large numbers of particles of vegetable matter, in part cellular tissue and in part epidermal tissue. An examination of tar coal showed only particles of amorphous resinous material, and it was only in impure specimens that any traces of plant cells either of bark or tissue were found, such as were so common in the brown coal. He therefore traces the origin of the fire coal (earthy brown coal) to the

* Ueber die Entstehung der Braunkohlen, besonders der Schweelkohlen, Halle a. S., 1889.

woody portion of the plant, and the pyropissite (tar coal) to the resinous matter it contained.

The tar coal, or pyropissite, forms bands or alternating strata with the fire coal, or is scattered through it in irregular masses. Prof. von Fritsch argues that the trees could not have grown at the locality of the brown coal deposit, for had that been the case there would have been an intimate mingling of the two materials both derived from the same trees, as is the case in other localities, but that they have been brought in from elsewhere, and the sorting action of the water has separated the tar coal from the fire coal by reason of their different specific gravities when brought to their place of deposit.

FORMATION.

Coal is produced by the chemical alteration of vegetable matter in the presence of water. And the processes by which the beds of coal were formed are in steady and gradual operation around us to-day.

These are:

1. The decomposition of the vegetable matter: a. In contact with air. b. Out of contact with air.

2. The deposition of the decomposed materials: a. At the place of its origin. b. At other localities.

3. The subsequent alteration of the deposits by slow or more rapid metamorphism.

I. THE DECOMPOSITION OF VEGETABLE MATTER.

a. In Contact with Air.—Vegetable matter, which is composed principally of carbon, hydrogen, and oxygen, when exposed to the action of the air undergoes change in two ways. It is partly oxidized by the air, or decays, and partly decomposed. In the process of oxidation or decay there is a loss of carbon as carbonic acid, and hydrogen as water, and the final resultant would be a pure carbon. This is believed by some to be the method of formation of the mineral charcoal which is found between the layers of many bituminous coals, and which consists of nearly pure carbon. Where the atmosphere is sufficiently moist, this final carbonization does not occur, but the process takes more nearly the form of mouldering.

b. Out of Contact with Air.—The change of vegetable matter out

of contact with the air, or in presence of very moist atmosphere, but more especially under water, is due to decomposition only, or moulder-ing, in which the elements which enter into the composition of woody fibre as expressed by the formula of cellulose $(C_6H_{10}O_5)_n$ are resolved into four combinations, water, carbonic acid, light carburetted hydrogen or marsh gas, and coal, and the character of the coal is determined by the relative amounts of each of these products which are formed. The formation of carbonic acid and marsh gas, the choke-damp and fire-damp of the miners, is constantly going on even now in coal seams, and if continued long enough would ultimately convert beds of bituminous coal into anthracite.*

The changes which take place in the formation of coal, as shown by microscopic examination of beds of peat,

"Are associated with the carbonization of the various materials and its further transformations. The experiments of Lindley and Goeppert show that the persistence of structure of plants immersed in water depends very much on the power which particular families of plants possess of resisting the decomposing action of water.

" The process of transformation becomes more and more apparent by the deposit of a black amorphous matter in and upon the walls of the cells, which, under the microscope, appears to be nothing but carbon, and at first occurs in a very definite manner. The granular deposit is noticed first in the interior of the cells and upon the walls of the tubes which compose the vascular tissue of the plants, so that the process of transformation appears to begin with these. This metamorphosis continues until the original anatomical appearance of recent vegetable tissue is completely destroyed, becoming opaque, granular, and amorphous by the deposit of the black substance.

" The evolution of gaseous products ruptures the cells, and the vascular tissue becomes separated, so that the cells and fibres gradually pass into an amorphous mass of a black color, or into an homogeneous yellow resinous-like substance.

" These are the changes which take place where the air is partially excluded, but when it has access the mass assumes a more earthy aspect and the elements of the tissues moulder down into granular particles. The gaseous products, when they can not bodily escape, tend to break up

* Le Conte, J. L. Elements of Geology.

For discussion of the changes in chemical composition which vegetable tissue undergoes during its conversion into peat and coal, compare also Percy's Metallurgy, "Fuel," p. 213, Dana's System of Mineralogy, p. 750, Bischoff's Chemical and Physical Geology, Vol. I, p. 274, *et. seq.*, Muspratt, etc.

the tissues as they become confined within the cells or between the tubes. The burial of vegetable matter in the earth thus shuts out the action of the air and exposes it to the action of mineral matter, either the result of its own decomposition or that of surrounding strata."*

"The vegetable material, in changing to ordinary mineral coal, has not passed necessarily through the state of brown coal. * * * Between these extremes of excluded air and very imperfectly excluded, and of pressure from heavy superincumbent earthy beds and little or no pressure, lie the conditions which attended the origin of the various kinds of coal, and determined, in connection with the nature of the vegetation itself, the transformations in progress."†

Capacci's table of the comparative values of carbon, hydrogen and oxygen in wood, brown coal, bituminous coal, and anthracite, with the combined amounts of hydrogen and oxygen equaling fifty per cent of the total weight in wood, thirty per cent in brown coal, fifteen per cent in bituminous coal, and five per cent in anthracite, show that the relations between the carbon and the hydrogen and oxygen would be respectively:

C=H+O in wood.

C=2.33 (H+O) in brown coal.

C=5.66 (H+O) in bituminous coal.

C=19 (H+O) in anthracite.

In other words, that the cumulative resolution or gradual elimination of the hydrogen and oxygen of the plant tissue or cellulose out of contact with air would, if it proceeded regularly and naturally for a length of time sufficiently great, cause the wood fibre to pass successively through the stages of peat, brown coal, bituminous coal, anthracite. This process may be accelerated by heat, moisture, and preasure, or it may be impeded or entirely stopped by exposure to atmospheric agencies or oxidation.

The relative proportions of the elements constituting the various kinds of fuels are given in the following tables from Groves & Thorp, to show that they are chemically derivable, as has been stated, by cumulative resolution:

*Groves and Thorp, Chemical Technology, p. 36.

†Dana, System of Mineralogy, 1888, pp. 758, 759.

OMISSION.

Capacci, Ing. Celso. Studi sulle Ligniti. Turin. 1890.

TABLE NO. 1.

	C.	H.	O.
Woody fibre	52.65	5.25	42.10
Peat	59.57	5.96	34.47
Lignite	66.04	5.27	28.69
Earthy brown coal	73.18	5.88	21.14
Secondary coal	75.06	5.84	19.10
Bituminous coal	89.29	5.05	5.66
Anthracite	91.58	3.96	4.46

TABLE NO. 2.

	C.	H.	O. & N.	Disposable H.
Wood—mean of several analyses	100.00	12.18	83.07	1.80
Peat	100.00	9.85	55.67	2.89
Lignite—mean of 15 analyses, including brown coal	100.00	8.37	42.42	3.07
Steam coal	100.00	5.91	18.32	3.62
Anthracite (Penn.)	100.00	2.84	1.74	2.63

The chemical decomposition was also attended to a greater or less extent by disintegration or maceration, and the degree to which this was carried before final deposition has had a great influence upon the resulting coal. Thus in the brown coals, it was least in the lignite and its varieties, greater in earthy brown coal, and its highest degree was reached in the process which produces glance coal and pitch coal.

II. THE DEPOSITION OF THE DECOMPOSED MATERIALS.

The places of deposition are:

In complete basins, marshes, lakes or lagoons.

Along the shores of lakes.

Along river banks.

In the river deltas.

Along the sea shore.

a. AT THE PLACE OF ORIGIN.—This may be accomplished in three ways:

1. Through the decay and deposition of sea plants.

The theory which considered all the coal beds as derived from such sea growth as occurs in the Sargossas is not now accepted, since the plants which occur there do not contain the necessary woody fibre. There are, however, certain small deposits which have been referred to such deposition from plants occurring along the sea coast and adjacent shore.

2. Through the submergence of forests.

Numerous examples of deposits formed in this way are found in the brown coal beds of Switzerland, Silesia, and elsewhere. In the United States a similar occurrence is noted at Drummond lake of the Dismal Swamp, which may, however, more properly belong to the deposits described below.

3. Through accumulations similar to those of the peat bogs of the present day.

Peat deposits are very scarce, if not entirely wanting, in this region, and few have had an opportunity of examining them. In his paper on the origin of coal, already referred to, Prof. Lesquereux describes their mode of occurrence and growth, and from this paper I have arranged the following description:

"The definition of a bed of peat is the same as that of a bed of coal. It is an accumulation of the remains of plants grown *in situ*, deposited each year, or after the cycle of their vegetation is completed, and superimposed without interruption, one layer upon another, until the accumulation becomes sometimes of great thickness, and covering a wide surface of land.

"Two conditions are necessary for the origin and growth of peat: water either stagnant in basins, lakes, pools, etc., or water abundantly supplied by a foggy atmosphere, increased by dense forest growth.

"Peat bogs in the low countries are more extensively formed along the sea shore, especially near the mouths of large rivers, like the Somme, in France; the Weser and Elbe, in Germany; along the shores of the North Sea, in Holland; and of the Baltic, in North Germany, Pomerania, Denmark, Sweden, etc. Peat is formed everywhere where an expanse of water has become enclosed as a water basin sheltered from the invasion of the sea by bands of sand thrown up by the waves; or along the river valleys, by the natural levees which border most great rivers in some parts of their course, especially near their mouths. These natural dams are made by the deposit of muddy matter in times of inundation; since currents make their precipitations along their border lines, where the force ceases to be active, and at a greater or less distance from the maximum line of flow, and parallel to it.

"Behind such natural dams or levees, wherever the inundations do not overleap, there remain shallow basins with impermeable bottoms of soft mud or clay. These are invaded by vegetation and transformed into peat bogs. Along the shores of the sea also the waves and winds create long sand dunes, some of which are very high. Behind these barriers small creeks and even rivers are arrested in their flow, their waters ex-

panding into shallow basins, which are invaded by plants and filled with peat deposits. These still retreats of vegetation are not always safe from disturbance; although sheltered for a time against the rivers or the ocean, it will happen that some extraordinary freshet, some extraordinary high tide, some tremendous storms, break down or through the barriers, and then the peat bogs become covered with a deposit of mud or sand.

"Pools of stagnant water, when not exposed to periodical drying up, are invaded by a peculiar vegetation, first mostly composed of confervæ, simple thread-like plants, of various colors and of prodigious activity of growth, mixed with a mass of infusoria, animalcules and microscopic plants, which, partly decomposed, partly continuing the floating vegetation, soon fill the basins and cover the bottoms with a floating clay-like mould. So rapid is the work of these minute beings that in some cases from six to ten inches of this mud is deposited in one year. Some artificial basins in the large ornamental parks of Europe have to be cleaned of such muddy deposits of floating plants, mixed with small shells, every three or four years.

"When left undisturbed this mud becomes gradually thick and solid, in some cases of great thickness, affording a kind of soil for the growth of marsh plants, which root at the bottoms of the basins or swamps and send up their stems or leaves to the surface of the water or above it, where their substance becomes in the sunshine hard and woody. As these plants periodically decay, their remains of course drop to the bottom of the water; and each year the process is repeated with a more or less marked variation in the species of the plants. After a time the basin becomes filled by these successive accumulations of years or even centuries, and then the top surface of the decayed matter, being exposed to atmospheric action, is transformed into humus, and is gradually covered by other kinds of plants, making meadows and forests. In this way many deposits of peat are buried under ground and remain unknown until discovered by diggings or borings. Such are the immense peat deposits in the great swamps of Virginia, the Dismal swamps, and all along the shores of the Atlantic from Norfolk to New Orleans.

"In other cases, when basins of stagnant water* are too deep for the vegetation of aquatic plants, nature attains the same result by a different special process, namely, by the prolonged vegetation of certain kinds of floating mosses, especially the species known as *sphagna*. These floating mosses grow with prodigious speed, and expanding their branches in every direction over the surface of ponds or small lakes, soon cover it

*This word should not be understood as water absolutely destitute of all movement, either by access or egress, but merely water not exposed to sweeping currents or great change of level. No peat can grow where the bottom of the basin is occasionally dry and exposed to the action of the atmosphere.

entirely. They thus form a thin floating carpet, which, as it gradually increases in thickness, serves as a solid soil for another kind of vegetation, that of the rushes, the sedges, and some kinds of grasses, which grow abundantly mixed with the mosses, which by their water absorbing structure furnish a persistent humidity sufficient for the preservation of their remains against aerial decay. The floating carpet of moss becomes still more solid, and is then overspread by many species of larger swamp plants, and small arborescent shrubs, especially those of the heath family; and so, in the lapse of years by the continual vegetation of the mosses, which is never interrupted, and by the yearly deposits of plant remains, the carpet at last becomes strong enough to support trees, and is changed into a floating forest, until, becoming too heavy, it either breaks and sinks suddenly to the bottom of the basin, or is slowly and gradually lowered into it and covered with water.

"The operation is nevertheless not yet complete, at least not always; for, after the sinking of the first floating carpet, the vegetation of the mosses may begin again at the clear surface of the water, and in the course of years or centuries—no matter how many, for nature is never in a hurry—a new carpet covers the basin, another cycle of vegetation begins and continues its course, until this second mass of vegetation, like the first, is pressed down under water. Thus we have two superposed beds of vegetable remains in process of slow decomposition, or subjected to the beginning of the transformation into coal. And both the layers are composed in the same way, the lower part being a mass of the remains of small vegetation, mosses, water plants, etc., the upper part covered with trees; that is, two beds of peat and two forests.

"This exposition has no hypothetical character whatever; it is merely a description of observed facts. In the southern part of the United States the results of the process are differently exhibited. The bottom of Drummond lake, of the Dismal Swamp, for example, is formed of a forest, once growing at the surface, but now prostrate and buried beneath fifteen or twenty feet of water. Beneath it probably lies a deposit of the detritus of plants, or a bed of peat; while the moss vegetation is now advancing into the lake from all around its edge; so that it is not possible to reach the open water without sinking deeply at every step into the floating carpet.

"The water necessary for the growth of the plants which compose peat, and for the preservation of the vegetable remains against rapid decomposition, is not always in the shape of standing water, ponds or lakes. An ordinary spring of water will answer the purpose. Or, as has been said above, the moisture of the air may suffice. In the first case, the operation depends upon the nature of a special kind of moss called *sphagnum*, already mentioned, which has a very peculiar conformation and in reality

is not a true moss, but constitutes a separate family of plants not properly related to any other kind. From the seeds which develop in water, the stems expand loosely in every direction, in floating tufts, which grow continually wider and thicker until the basin is entirely filled by their vegetation.

"In the other case, upon land surfaces where but little water is at hand for their original development, they grow in compact tufts (the stems not thicker than coarse thread) compressed upon each other, their branches and leaves being endowed with the peculiar property of absorbing moisture by their outer tissue, and imbibing it like a sponge. In this way they obtain sufficient moisture to sustain their growth. But under certain circumstances, when the atmosphere itself contains less moisture than the mosses hold in their tissue, they have the faculty of absorbing water by their stems and leaves from below, taking it up to the surface of their leaves, where it is evaporated into the atmosphere.

"The growth of these mosses is not limited to seasons. Although its activity in freezing weather stops for a time, it is resumed as soon as the temperature rises above 32 degrees; and, as these mosses are constantly filled with water in such a degree that it can be squeezed from a tuft as it can be squeezed from a soaked sponge, they furnish the best kind of ground for the germination and growth of a large number of aquatic and other plants; which in fact germinate in these humected tufts of moss quite as well as they could do upon wet ground. These mosses, therefore, covering, as they often do, very wide areas, play the same part upon land surfaces as they do upon the water basins over which they float, the only difference being that on land surfaces their substance is far more compact.

"Each year the peat bogs grow higher and higher, not merely by the yearly additions to the surface of the mass of *sphagnum* (and other plants mixed with it), but also by the added bulk of whatever woody remains get buried beneath the growth of moss. For, as soon as the moss bogs have become sufficiently compact, certain kinds of trees, like the tamarack, the bolled cypress and the birch in North America, and the smaller species of pines in Europe, are apt to invade their surfaces. The roots of these trees become covered by the mosses, which build up their high tufts around them, protecting from the decomposing action of the atmosphere not only the roots of the growing trees, but all such leaves, branches, pieces of bark, cones, etc., as may fall upon the moss-covered surface.

"When the atmosphere is very humid, or where the supply of water is furnished by some rivulet traversing the swampy plain, the peat grows upward rapidly and to a great thickness. In the great peat bogs of Les Ponts, Jura, the thickness of the peat is found to vary between 8 and 30 feet. In some provinces of Russia the growth of peat is officially reported

to be 50 and even 100 feet thick. In mountainous, foggy regions the absorbent ability of *sphagnum* makes peat bogs grow even on steep slopes, which become, for this reason, more or less impassable. The mountain sides near the summit of the Brocken (the highest of the Hartz mountains) are sheeted with large boulders of rock, covered over and filled in between with moss, which thus makes a continuous carpet.

"The absorbing powers of the peat mosses enables them to grow higher and higher above their original water level, from which they thus gradually emerge. The name emerged bogs has therefore been given to them.

"The peat of emerged bogs is less compact, the annual layers are more distinct, generally well defined in their succession. At the top of the bog the layers measure about one inch in thickness; at the bottom less than one-eighth inch; and in old bogs still less. The growth therefore, though not very rapid, is easily observed and registered.

"The rate of growth depends of course on atmospheric or other local circumstances, but, putting together many such pieces of documentary testimony obtained in different countries, the average production of compact matter may in a general way be estimated at one foot in a century.

"In *emerged bogs*, formed of vegetable debris falling into water, the peat grows more slowly and less regularly. The actual rate of its growth has not yet been positively recorded. In very extensive bogs, stretching between Swiss lakes, timber posts have been discovered on the line of an old road, and part of a bridge buried beneath five or six feet of compact black peat. Although the exact date of these constructions has not been fixed, the discovery of Roman medals in the vicinity suggests the beginning of the Christian era. This shows that the kind of peat which results from the maceration of plants under water is of much slower growth than the peat layers of the *emerged bogs*. It is also more compact, and is quite black, the vegetable matter being more completely decomposed, and its internal structure generally so destroyed as to be unrecognizable. The peat of *emerged bogs* on the contrary is yellowish-brown, fibrous, its annual layers distinct, and the woody fragments more generally recognizable.

"That the earth's atmosphere was thoroughly saturated by vapors in the Carboniferous period is fully evidenced by the character of the flora of that epoch. The great thickness of the Carboniferous vegetable deposits is in accordance with the probable fact of an excessively humid atmosphere; for it is well established that all of the deposits of *immersed peat* are generally thin. The beds of cannel coal, which are the ancient representatives of such lake bogs, are usually thinner than those of bituminous coal.

"It must, however, be kept in mind that all the agencies which con-

tributed to the formation of coal beds worked on a prodigously larger scale than those which are now in activity for the formation of peat. Then, the deposits of vegetable remains were from an exceptionally exhuberant vegetation, favored by the greatest possible humidity of the air, and a superabundance of carbonic acid in the atmosphere. It was a vegetation of which we can scarcely get an idea from anything now visible. Acrogenous plants, Ferns, Lycopods and Equiseta (Horsetail) composed nearly the whole flora of the coal period. All the plants of those orders, represented by numerous genera, were then large trees, their trunks measuring from one to three feet in diameter, 40 to 100 feet tall, or even more, growing close together, and forming an impenetrable thicket of stems, branches and leaves; whereas, at the present day, the same kinds of plants are represented by mere herbage of small size, with stems and branches scarcely as thick as a goose quill, and only one or two feet high. Most of the land surface was then a vastness of swamps, in which the first growth, generally floating or creeping plants, was essentially composed of a peculiar species, the Stigmaria, whose immensely long stems and branches, from four to six inches thick, were woven together, like the thin, matted, floating stems of the Sphagnum of the present age, into an immense woven mat, or thick carpet, over which the luxuriant land vegetation of the coal soon spread itself. And, of course, we must suppose that such an accumulation of ponderous materials, such a mass of vegetation, sank of its own weight at times and places into the water beneath and became wholly submerged. This supposition becomes a certainty in view of the superposition of thick beds of sandstone, shale, clay, ironstone and limestone upon the old beds of coal."

This description applies as well to the formation of certain deposits of brown coal as it does to those of bituminous coal. In some cases it is entirely possible from the character of the brown coal itself and from included materials to designate a certain deposit as having been formed in a submerged bog, while another is similarly shown to have been from an emerged bog. Thus the coal formed in the emerged bog is distinguished by its greater purity, less content of ash, and the scattered fragments of lignite occurring through it. These beds often contain roots of ferns.

b. At Other Localities.—While a certain portion of our brown coal was formed in this manner, there are nevertheless great quantities which owe their origin to conditions somewhat analogous to those of the gulf coast of the present day. Stretching along the entire water front were bays and lagoons into which the rivers of Tertiary times poured their floods of water, carrying in solution and in suspension sand and clay and

lime, and bearing on their bosoms the drift gathered from the forest-covered hillsides through which they passed.

The variety and luxuriance of the timber growth of that period is fully certified to us in the character and size of those portions of it which have come down to us in petrified condition and in the great beds of fossil leaves which are found at many localities. And the mouldered material, fresh plant portions, and soil masses carried down in this way have given rise to many of the beds of earthy and common brown coal with their interbedded clays or sands.

In the fresh water basins great regularity of structure is exhibited, and the interbedded materials consist principally of plastic clay, and the coarser sand or pebble beds are entirely wanting. These latter, coarser or finer, are characteristic of the littoral or estuarine deposits.

"During the formation of the Carboniferous beds,* all the rivers whose banks were covered with wood carried immense masses of drift-wood down into the sea, as the large American rivers do at the present time which are flowing through wide tracts of uncultivated lands. The culture of land has rendered circumstances quiet different. The banks of rivers have become arable and meadow land, while the woods have been destroyed for some distance from the banks. On this account, the quantity of drift wood carried down by rivers flowing through cultivated land has become much less than that which they conveyed to the sea in prehistoric ages. Not only were trees and shrubs torn up by the roots by floods, but also the decayed remains of plants were swept into the stream and carried into the sea. Every small brook and stream, overcharged after long rain or the melting of the snows, was laden with these substances. At this period, when a greater part of the earth's surface was covered with luxuriant vegetation, these waters carried almost only decaying vegetable matter along with them; while at the present they carry down far more inorganic matter, derived from cultivated land, than organic matter, the quantity of which is small since the crops are collected. Organic matter is, however, found upon analyzing the suspended matter of rivers; in that of the Rhine it amounts to 3.31, and in the mud of the Nile to as much as 5.5 per cent.

"The trunks of trees float in water, but if they retain their roots, which are often laden with earth and stones, they readily sink, especially when soaked through with water. The trunks of trees, such as form the drift-wood of the Mackenzie river in the Slave lake† suffer a gradual decay, until they are converted into a blackish-brown substance resembling peat;

*Bischoff, Chemical and Physical Geology, Vol. I, p. 295.

†Dr. Richardson, in Lyell's Principles, p. 716.

the layers of this often alternate with layers of sand and clay, the whole being penetrated by the long fibrous roots of willows, which grow on their trunks as soon as they appear above water. A deposition of this kind would produce, says Lyell, an excellent imitation of coal, with impressions of the willow roots. The banks of the Mackenzie present almost everywhere horizontal beds of wood coal, alternating with bituminous clay, gravel, sand, and friable sandstone; sections, in short, of such deposits as are now forming at the bottoms of the lakes which it traverses. This wood coal, after having been converted into this blackish-brown substance, can not fail to be rubbed off and carried into the sea during high water. A very great mass of driftwood is found where the Mackenzie reaches the sea.

"When stems of trees are converted into fine powder, by decay or mechanical means, it sinks in still water. This is the case not only with heavy woods, such as oaks, beech and pine, but also with willow wood. It is only imperfectly decayed ligneous fibre which floats. Decayed spongy beech wood, sometimes quite bleached, and in which the inside wood is often altered, sinks when rubbed to powder; not, however, till after some days, if it be in large pieces. Some dark brown pulverulent ligneous fibre, resulting from the decay of heath plants, which I found in a forest, washed into the road by a heavy rain, sank immediately in water. Oak, fir, and poplar sawdust likewise sink, but splinters float in water. Even finely powdered dead leaves sink. The particles of wood, whether decayed or mechanically divided, also sink in sea water. There is no doubt that it is merely necessary to displace the air in wood by water in order to cause it to sink.

"In the moving waters of rivers, finely divided decaying vegetable substances are not deposited, or at most, only temporarily; they are therefore carried into the sea or lakes, and sink in still water. This is also the case with the same kind of substances swept into the sea by the waves dashing upon the shore, and by the tides.

"Although these organic substances are but little denser than water, while the inorganic matter suspended in river waters is two and a half or three times as dense as water, the former sink much sooner than the latter. Muddy Rhine water does not become clear until after it has stood four months. If, therefore, decayed vegetable matter and finely divided inorganic matter are simultaneously carried into the sea, very little of the latter sinks with the former. For this reason the inorganic matter of coal always amounts to less than the carbonaceous, as is evident from the analysis of coal and brown coal.

"It is easy to imagine that in prehistoric ages the quantity of decayed vegetable substances (vegetable detritus) carried into the rivers must have amounted to much more than that of the trees actually carried into them

as such; for only the trees torn up from the banks and steep declivities of the rivers came into them in a perfect state, and not those which died upon the highlands and slight declivities. It was not until after these were decayed that they could be carried away by water. Then the area of the high plains and the slightly inclined land is, when the rivers flow through narrow valleys, far greater than that of the overflowed banks and the steep declivities. The dead trees upon slight inclinations are more or less fixed to the ground by their roots, and, like blocks of stone in the same position, are not carried away by the streams until after they have suffered decomposition."

III. THE SUBSEQUENT ALTERATION OF THE DEPOSITS BY SLOW OR MORE RAPID METAMORPHISM.

As has already been stated, the decomposition which is the principal factor in the formation of the coal, does not cease with its deposition and its subsequent covering by beds of sand or clay, which may in time be hardened into rock, but continues its action indefinitely. This action may be accelerated by an increase of heat arising from greater pressure, earth movements, volcanic action or otherwise, and thus produce, from what would otherwise be a brown coal or lignite, a bituminous coal or even a variety of anthracite. When such acceleration is not applied the changes are of course very slow, and such derivation of anthracite and graphite without acceleration has not been definitely proved.

PHYSICAL CHARACTER OF BROWN COAL.

SPECIFIC GRAVITY.—The specific gravity of brown coal varies from 0.8 in pyropissite (which is often classed among them, although more properly a resin), to 1.5 in other varieties. This can only be regarded as an expression of the density itself if the coal is sufficiently clear from extraneous admixtures or ash. Zincken recommends that in determining the specific gravity of brown coals the specimen, after being weighed in air, and previous to being weighed in distilled water, be freed from the greater part of its absorbed gases under the receptacle of the air pump. This is the only way of securing anything like accurate results, and with lignitic coals requires a long continued exhaustion to obtain a proper determination.

HARDNESS.—The hardness of brown coal varies from that of bituminous coals to that of peat.

COHERENCE.—Brown coals vary from a soft, earthy material through all grades of compactness and toughness to that which renders it necessary to mine it by blasting. Lignitic varieties are sometimes flexible and elastic.

CLEAVAGE.—The earthy, or common brown coals, show no cleavage; the lignitic, however, have a cleavage in the direction of the grain of the wood. Certain pitch coals, or glance coals, also show slight cleavage parallel to the stratification planes.

JOINTED STRUCTURE.—Vertical joints are very common in beds of brown coal, and in glance coal and pitch coal these are so arranged that they fall apart in fragments of cubical or parallelopipedon shape.

FRACTURE.—The fracture is even to uneven, smooth, slightly to completely conchoidal, crooked, angular, granular, splintery, schistose, and earthy in brown coals, and fibrous in those of woody texture.

COLOR.—The color of brown coal varies from light yellow through all shades to the darkest brown and black.

LUSTRE.—Brown coals possess a variety of lustres, such as dull, waxy, pitchy, greasy, vitreous, and metallic.

STREAK AND POWDER.—The streak and powder of brown coal vary from light to dark brown, and is usually of a lighter shade than the mass. If the brown coal be scratched, the scratch shows a surface more or less shining. The earthy varieties often assume a greasy appearance if rubbed with the finger nail. Fötterly states that the streak and fine powder are the safest criteria for distinguishing stone coal from brown coal, as these are always black in the former and brown in the latter, but Zincken takes exception to this on the grounds stated elsewhere.

Everhart gives, as a characteristic of brown coal, that a piece of it dipped in water and held to the ear emits a peculiar crackling sound, which is not given out by bituminous coal under similar circumstances.

CONTENTS OF BROWN COAL IN HYGROSCOPIC WATER.—The hygroscopic water contained in brown coal varies with the variety of coal and the length of time which it has been mined. The variety of brown coal which has the least amount of water is a glance coal and pitch coal of Salesl in Bohemia, which only carries about two per cent. From this amount it gradually rises in the different kinds until in the freshly mined earthy brown coal of Germany it often amounts to fully one-half the entire weight. The table given below shows the relative amounts of hygroscopic water in some of the European brown coals.

TABLE NO. 3.

Amount of Hygroscopic Water in Representative Brown Coals of Europe.

Salesl	Bohemia	Glance coal	2.00
Miesbach	Bavaria	Pitch coal	5.36
Tokod	Hungary	Glance coal	10.86
Teplitz	Bohemia		17.25
Casteani	Italy		17.00
Falkenau	Bohemia	Brown coal	19.03
Dux	Bohemia	Brown coal	25.00
Gloggnitz	Austria	Lignitic brown coal, much fissured.	25.00
Schallan (Teplitz)	Bohemia	Brown coal	28.80
Bovey	England	Brown lignitic (Miocene)	34.66
San Giovanni	Italy		40.00
Halle a. S	Germany	Earthy brown coal	45.00

A part of this moisture is readily dissipated on exposure to air, and to this fact is due to a large degree the quality possessed by brown coals of slacking or crumbling when so exposed. Even after long exposure to the air many brown coals contain as much as fifteen to twenty per cent of moisture. This water may be driven off by heating the coal to a temperature of 100 degrees C., or a little higher, but if it is left open to the atmosphere it will reabsorb as much as it lost.

TABLE NO. 4.

Moisture Absorbed per 100 Pounds of Dried Brown Coal.

Hours and Minutes.	Gloggnitz. (Austria.)	Tallern. (Austria.)	Westerwald. (Nassau.)	Westerwald. (Nassau.)	Grumbach. (Austria.)
0.15	5.50	3.50	2.10	1.40	1.50
0.30	....	4.70	3.50	2.90	3.00
0.45	....	....	5.40	4.10	....
1.00	8.40	5.30	6.50	4.80	3.70
2.00	....	....	....	....	....
3.00	....	....	....	9.50	....
4.00	....	....	....	....	....
5.00	....	....	10.70	....	....
6.00	....	....	....	13.40	....
7.00	....	....	....	....	....
8.00	....	....	....	14.80	....
12.00	14.90	9.60	....	....	6.40
24.00	15.90	12.70	....	....	6.60

ASHES OF BROWN COAL.—In addition to the inorganic matter contained in the woody substances from which the coals are derived, they contain

greater or less amounts of mineral matter which have been deposited with them from solution or suspension in the water in which they are laid down. The amount of such material varies widely, not only in different beds, but in different parts of the same bed, or even from different parts of the same lump. The ash consists principally of silica, alumina, oxide of iron, lime and alkalies. It may lessen the value of the coal in two ways: first, by its existence in the coal in too great quantity; second, by the presence in it of the iron or alkalies in such proportion as to form "clinkers" by fusing. The color of the ash is often a fair indication as to the amount of iron present, those white to gray in color being low in that metal, while the various shades of red indicate its presence in corresponding quantities. It usually occurs in the form of pyrites.

CHEMICAL PROPERTIES OF BROWN COAL.

The chemical properties of brown coal are twofold: First, its composition; that is to say, the elements of which it is composed and the relative quantities of each contained in it. Second, the action of chemical reagents upon it. Of these the first is by far the more important for our purpose; but while the latter have no special bearing on its fuel value, they are given for comparison.

Two methods are used for the purpose of ascertaining the composition of brown coal. The first of these merely determines the relative proportion of water, compounds of carbon, hydrogen and oxygen, ordinarily reported as "volatile matter," fixed carbon and ash, which together constitute the coke if one is formed. This is called proximate analysis.

The water is determined by heating the powdered coal to 105 degrees C. (care being taken to avoid oxidation), until the weight is constant. The volatile matter is determined by subjecting a weighed quantity of the carefully dried coal to a dull red heat in a platinum crucible until the volatile matters are driven off, and their quantity is then determined by loss of weight. The remainder consists of the "coke," or fixed carbon, and the ash. This part of the analysis can not be made by the method commonly used with bituminous coals of heating them strongly in blast flame for three minutes and reckoning the loss of weight as volatile matter, since this not only brings about combinations of the carbon and disposable hydrogen of the brown coals, which are volatile at the temperature employed, but from the physical peculiarity of the brown coal an appre-

ciable quantity of it is carried off unburned if finely powdered, when the blast and high heat are used. This gives the amount of volatile matter a much higher ratio than that actually existing, and the fixed carbon a correspondingly lower one. The amount of ash is found by carefully burning the coke left in the preceding operation in an open platinum crucible until the carbon is perfectly consumed and the ash assumes a clear appearance. This is the method of analysis most often followed, but while it gives an idea of the character of the coal, it does not furnish the requisite data for an accurate calculation as to its real value.

A modification of this method of analysis for fuel valuation is often used to ascertain the suitability of the brown coals for other purposes, such as the production of paraffine, oil, tar, etc. This is called fractional distillation.

The other method is an ultimate analysis of the coal—a separation of its elementary substances—carbon, hydrogen, oxygen and nitrogen, which is usually accomplished by combustion with oxide of copper, preferably with the use of a boat of platinum or other substance in a stream of oxygen supplied by a gasometer. In this method, which is substantially that commonly used in all organic analyses, the carbon and hydrogen are burned to carbonic acid and water, separated and weighed, and the loss taken as representing the oxygen and nitrogen, or the nitrogen may be determined by the ordinary methods. The process is carried on in a tube of difficultly fusible glass or platinum, which is connected on the one hand with the gasometers holding oxygen and air, by bulbs containing caustic potash and chloride of calcium, to absorb all carbonic acid and moisture that may be in the air and oxygen, and on the other with similar tubes to collect the products of combustion. The combustion is made in the usual manner, and the amount of carbonic acid and water produced are ascertained from the difference in weight of the collection bulbs of caustic potash and chloride of calcium before and after combustion. From these amounts the total carbon and hydrogen of the coal can be easily calculated, and if a boat has been used it contains the ash, which can also be weighed. An analysis of this character gives data for the calculation of the calorific value of the fuel, and is, properly speaking, the only reliable basis for such a determination.

According to Fremy,* lignites are partly dissolved in alkalies with

* Zincken, p. 10.

formation of ulmates, which color the solution dark brown. They are completely dissolved by hot nitric acid into a yellow solution, in which the insoluble resins float and are also dissolved by hypochlorite of soda, leaving only traces of colorless pith.

The earthy, compact, and black varieties of brown coal dissolve either very slightly or not at all in alkalies; they produce scarcely any ulmic acid, are soluble in nitric acid with separation of the resin, and are completely dissolved by hypochlorite solutions, as well as in a mixture of sulphuric and nitric acids, to a substance similar to ulmic acid, which is precipitated by water.

Bituminous coal and anthracite, on the other hand, are not acted upon by hypochlorite of soda and alkalies, and only slightly, and after a long time, by nitric acid. The ulmic acid-like body produced by solution in nitric and sulphuric acids can also be precipitated by water.

Percy's experiments on the reaction of various reagents nitric acid, sulphuric acid, hypochlorite of soda, and potash, on anthracite, bituminous coal, and lignite, where the action was allowed to go on several years, shows that the reaction is greatest in the lignites, less in the bituminous coal, and least of all in anthracite.

CLASSIFICATION OF TEXAS BROWN COALS.

The following table will represent the different varieties of brown coal which are found in Texas, with the European equivalents.

TABLE NO. 5.

Texan.	German.	French.	Italian.
Lignite	Lignite	Lignite xiloide....	Piligno.
Earthy brown coal	Erdige Braunkohle	Lignite terreux...	Lignite terrosa.
Brown coal.....	Braunkohle.....	Lignite brun.....	Lignite bruna.
Pitch coal	Pechkohle	Lignite sec.....	Lignite secca nera.
Glance coal.....	Glanzkohle	Lignite piciforme	Lignite grassa nera (picea).
Jet	Gagat.....	Jais.....	Giajette.

The different species are not only separable into varieties, but also grade almost imperceptibly one into the other.

LIGNITE.

Under this name are included portions of wood—trunk, stem, leaf, or root—more or less fossilized and altered into brown coal; yellow to dark brown in color, and with a fracture varying according to character of the wood from which they are derived. It is not infrequently the case that there can be found in a single piece woody structure and particles altered into earthy, pitch, or glance coal.

Lignite occurs in single trunks or particles scattered through the sands, and as logs imbedded in deposits of brown coal of different varieties. Much of it as it comes from the mine retains its form and character so completely as to be almost indistinguishable from the ordinary wood of the present time, except that it is somewhat darker in color. It is frequently the case that such a log will be part lignite and the remainder silicified wood.

Lignite is formed principally of coniferous woods, less often of endogenous woods, peat and water plants.

The trunks of trees which are altered into lignite are seldom found standing at the locality at which they grew; and if they are, it is in a broken condition. They are more often found in horizonal positions, generally flattened, so that their breadth is to their height as 1: 3 to 1: 15.

Certain deposits of brown coal consist of a bed of material in which the whole mass shows the wood structure more or less completely preserved, and these are designated as lignitic brown coals.

The varieties of lignite are based for the most part on the kind or portion of wood from which they are derived, such as bark coal, leaf coal, reed coal, and others.

Moor coal is the name given to accumulations of the smaller portions of plants which are so finely divided as to show no woody structure, but serve as the resting place of masses of lignite derived from swamp growth or woody roots, trunks, etc., and is the most common companion of lignite deposits.

EARTHY BROWN COAL.

Earthy brown coal, through the more complete maceration of the plant material of which it is formed, is entirely amorphous, and shows no wood structure. In color it varies from yellow, through various shades of

brown, to brownish black. It is friable and earthy in structure, whence its name. It frequently contains quantities of lignite, and is usually accompanied by retinite, amber, and pyropissite. This latter is known as "Schweelkohle," and is the base of the great paraffine industry of Germany.

In its ordinary condition it contains as much as forty-five or even fifty per cent of moisture. While it somewhat resembles our Texas brown coal, especially in the fatty streaks which occur in it, the German is much more friable than ours, and also much inferior to it in heating value in the raw state on account of the great percentage of water it contains. This is the character of brown coal that is found most largely developed in the district around Halle a. S., and in the Rhine provinces. Much of it lies very near the surface, in beds varying from a few inches to sixty feet in thickness, and is most often mixed with schweel coal to a greater or less extent. From this variety of brown coal is manufactured the "nass-press-stein" and brown coal briquettes without bond.

Cologne earth or umber is a variety of earthy brown coal.

According to Roscoe & Schorlemmer and Dana earthy brown coal is "not a true coal, inasmuch as a considerable portion of it is soluble in ether and benzene, and often even in alcohol, whereas true coal is nearly, if not quite, insoluble in these liquids."*

The suggestion is made that the soluble portions may represent the pyropissite or other resins contained in this variety of brown coal.

BROWN COAL.

Brown coal, or common brown coal as it is sometimes called, is described by Zincken as follows:

"Compact more or less firm and solid masses, with traces of woody structure in parts. Structure compact passing into earthy, fracture even to somewhat conchoidal, lustre dull or slightly shining. Color from light brown to blackish-brown, and with a greasy, shining streak. It is intermediate between earthy brown coal and pitch coal."

This variety of coal is that which is most common in Austria, where it is associated with pitch coal and glance coal. It is also a variety found very generally distributed in our Texas deposits.

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*Treatise on Chemistry, Roscoe & Schorlemmer, N. Y., 1888, vol. 1, p. 598. System of Mineralogy, J. D. Dana, N. Y., 1888, p. 755.

PITCH COAL.

The next step in the cumulative resolution of the woody matter from which the brown coal is formed produces pitch coal, a compact coal of blackish-brown to pitch black color, with a waxy or greasy lustre, and a fracture uneven or slightly conchoidal. Its streak is brown. It most frequently occurs as a stratum or strata in other deposits, but sometimes occurs alone. The coal of the Bohemian basins is very largely a mixture of common brown coal (of somewhat drier nature than the German) and pitch coal, together with some lignite, and in this is very similar to the larger part of our Texas deposits.

GLANCE COAL.

This is the firmest and hardest variety of brown coal. It is compact in structure, usually possessing perfect conchoidal fracture and glassy or metallic lustre. It sometimes yields a coke. It occurs with brown coal and pitch coal as well as separately, and in certain places in Europe has been formed from the varieties named by the influence of the eruption of phonolite, basalt, trachite, etc., while at other localities no such agency can be found to account for its occurrence.

CHAPTER III.

BROWN COAL AS FUEL.—DIRECT FIRING WITH BROWN COAL. GAS FIRING WITH BROWN COAL.

The principal use of brown coal is, of course, for fuel purposes. Its proper and profitable application to this purpose has been brought about in three different ways. In the first place, by means of suitable appliances, it has been found possible to use the brown coal just as it comes from the mine for all kinds of domestic and manufacturing purposes. In the second place, by the preparation of an artificial fuel from it, it has been found possible to use it in the same manner and under the same conditions as bituminous coal. And in the third place, by the manufacture of producer gas from it, it has come into use in many metallurgical and manufacturing operations.

The most available fuel is that which can be used with least preliminary preparation. Hence we have such general use of wood and stone coal, even in localities where the same amount of heat could be obtained from fuel in other forms at the same or even less expense.

Therefore, in so far as it may be practicable, we should, where cheapness is the principal point, use the brown coal just as it comes from the mine.

If we consider the means of utilizing our brown coal raw, i. e., as it comes from the mines, without any preliminary preparation, we must observe the following facts:

First. The moisture it contains when freshly mined, and sometimes after long exposure to air, amounts even in the better brown coals, on an average, to about 11 per cent of their total weight, while that of the coals in use, as shown by analyses, is only 3 per cent. This surplus of 8 per cent must be evaporated by the heat evolved in the combustion of the brown coal, and lessens its fuel value to just that extent. Therefore we are confronted in the outset by the fact that under similar conditions a greater amount of raw brown coal will be required to accomplish a given amount of work than would be required with bituminous coal.

Second. This moisture, in addition to the effect it has in diminishing the heating power of the brown coal, is also considered detrimental from the further fact that its evaporation causes the brown coal to crumble or slack, and this happens whether the evaporation takes place in the open air at ordinary temperature or in the furnace.

This has been one of the principal objections to our brown coal as fuel. It is, however, a fact well known to those of us who have tried it, that this slacking goes on very slowly; indeed, if the brown coal be sheltered the slacking is very small in amount, and even when exposed the slacking goes on, it seems, only until a comparatively thin mantle of fine coal has covered the entire pile, and then is very much retarded, if not stopped altogether.

For this reason it is possible to store brown coal to much greater advantage than is generally supposed, even when the furnaces for which it is intended are only arranged to burn the lump coal. If, however, the furnaces be adapted for fine coal, this slacking is not detrimental save as the same condition applies to all coals from slight loss of heating power by exposure.

While it is possible to overcome this tendency to slack by the process of converting the brown coal into briquettes, and while it is also true that for many purposes this is by far the most desirable form of fuel and will always commend itself by reason of its many good qualities and advantages for domestic, railroad and steamship use, there are still many branches of industry which require the cheapest possible fuel, and if the brown coal in its raw state can be successfully applied to meet their requirements it will be greatly to their advantage. Such application has been found entirely practicable, and the work has even gone further, and not only have suitable grates been constructed for heating steam boilers, etc., for industrial purposes, but stoves for household use, apparatus for utilizing brown coal in metallurgical and industrial heating of all kinds, and even in locomotives, have been put into use with satisfactory results.

Such use requires, however, as has been repeatedly stated, an arrangement of fire boxes, grates and draught in such a manner as will suit the peculiarities of the fuel. When this is done raw brown coal is proved in use to be as available a fuel as any.

The methods of use are broadly separable into: 1. Direct firing. 2. Gas firing.

In the first of these the combustion is completed in the fire box directly in connection with the boiler or what is required to be heated. In the second the material is gasified only in the fire box or producer and conducted elsewhere for use either directly or through regenerators.

DIRECT FIRING.

STEP GRATES.

For all industrial purposes, and especially in making steam, the very best results in direct firing are secured from the brown coal by use of the step grate—the treppenrost—of the Germans. This differs from the flat grate in ordinary use at present in its greater angle of inclination and in the form and position of the grate bars themselves.

In the ordinary grate the bars stand on their edge, run lengthwise of the fire box, and the grate is horizontal or rarely slightly inclined. In the step or stair grate the bars lie on their sides, run across the fire box, and the grate is inclined at an angle of 29 to 40 degrees.

The inclination of the grate is varied according to the fuel to be burned, the rule being the finer the fuel the higher the angle of inclination; or conversely, the coarser the fuel the flatter the grate.

This grate is intended for use with all fuels which are in a more or less pulverulent condition—sawdust, spent tanbark, breeze or slack coal, etc.; but more especially for brown coal or lignite, and is used for all purposes, either in direct, half gas, or gas firing.

The grates from which the drawings here reproduced on Plates II and III were made are those in use at Donawitz and Zeltweg, in Styria, where I found them burning brown coal very closely resembling that which we have in Texas in character and in composition. The measurements which are given in the drawings are all millimeters, of which 25.4 are equal to one inch.

These are the simplest of the forms in use and represent two kinds of the step grate as applied to stationary boilers. The upper drawing of each plan gives the vertical section of the grate and boiler, while from the ground plan at the bottom it will be seen that the grate bars under each boiler are in three sections. The simpler form of the step grate is shown in Plate II. At the bottom of this grate a wrought iron support, four by six inches, extends across the furnace, and is built into the walls from three to five inches in order to make

it secure. On this support rest the string boards which carry the grate bars. These string boards are supported at the top by a double "T" beam, fastened in like manner as the first at the foot. These string boards are of cast iron, and the details of one of the centre ones are illustrated in Fig. No. 1. Those at the sides of the furnace are often let into the ma-

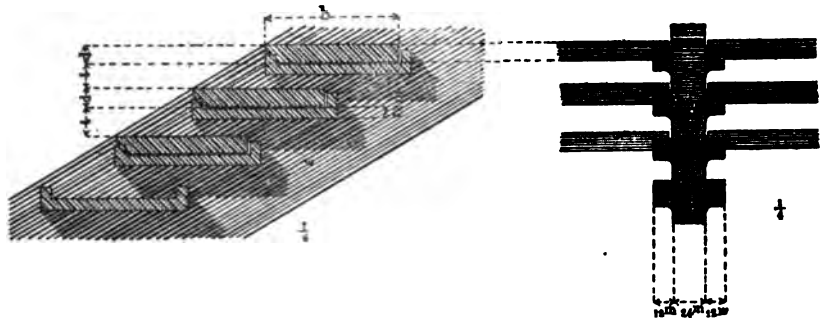


Fig. 1. String board with seats for grate bars.

sonry one-half inch or more. They have usually a thickness of an inch to an inch and one-half and carry the proper seats for the ends of the grate bars. The dimensions given for the one figured are:

Thickness of string boards	1 inch.
Width	5 to 6 inches.
Length	4 ft. 6 inches.
Thickness of iron seat	½ inch.
Iron seat extends from string board	½ inch.

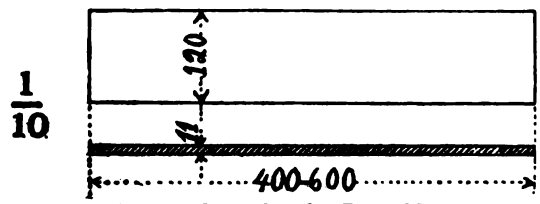


Fig. 2. Grate bar for Plate II.

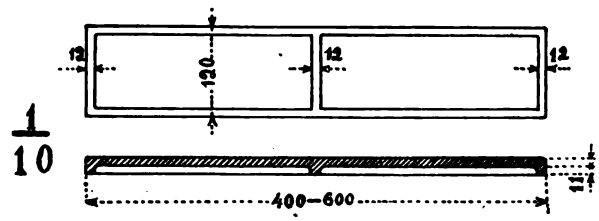


Fig. 3. Grate bar for Plate III.

The steps for grate bars, which are carried by the string boards, and which are shown in Figs. 2 and 3, have the following dimensions:

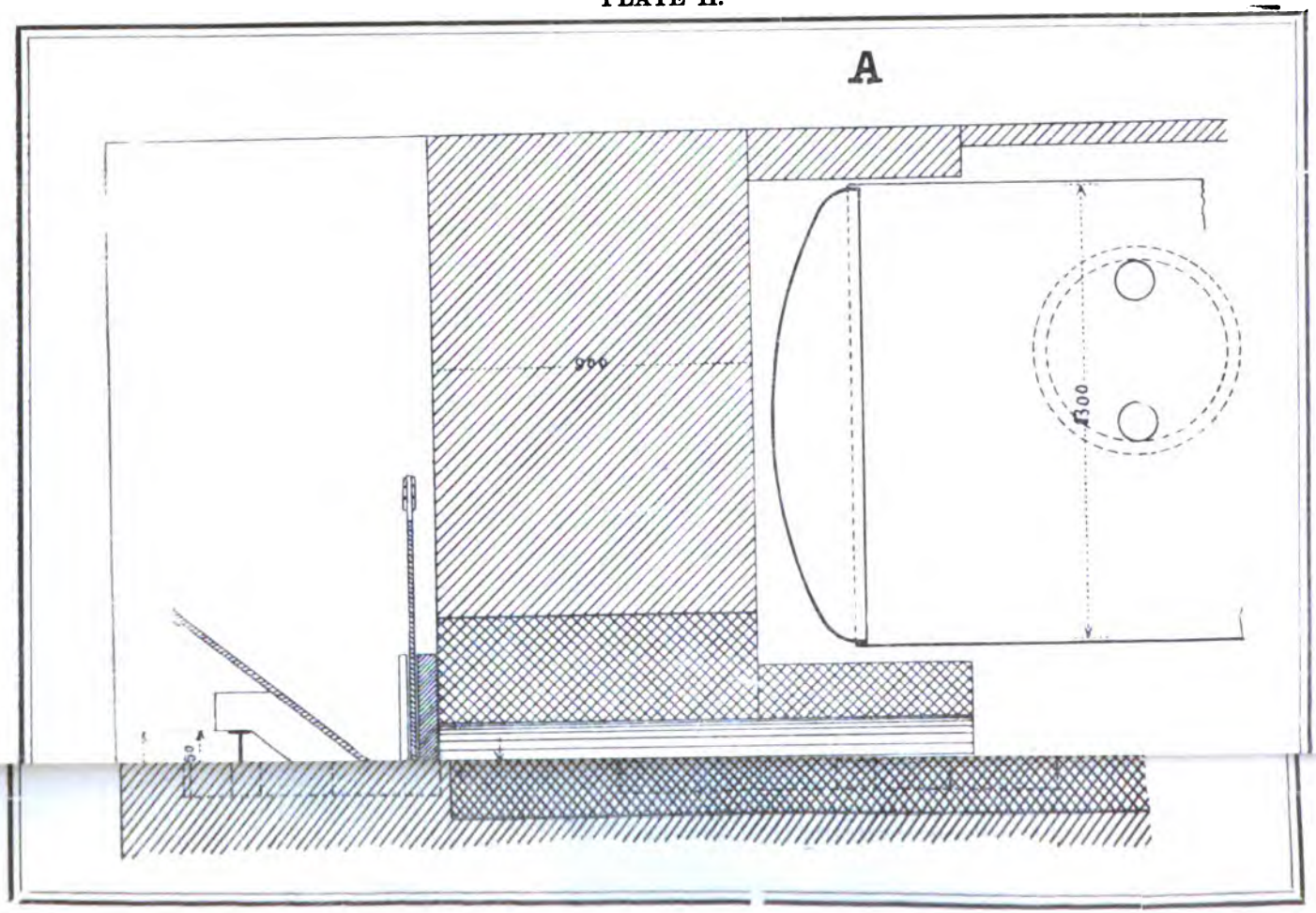
Length	16 to 24 inches.
Breadth	5 to 6 inches.
Thickness	½ to ¾ inches.
Distance between steps	⅞ to 1½ inches.

At the top of the grate in Plate II there is an iron plate 24 to 30 inches long, while another plate of equal size works in a slide against the boiler. These two form the hopper into which the fuel is thrown and whence it is fed into the grate. In this style of grate the bed of coal on the grate bars is held in place by the bank of ash and coal shown at the bottom of the grate and in ash pit. The measurements given for the opening of the hopper for the different sizes of coal are as follows:

For Slack Coal No. 2 (passing through mesh ⅜ inch square):	
Width of opening of hopper	1¼ inches.
Angle of inclination of grate	38 degrees.
For Slack Coal No. 1 (passing through ⅝ inch mesh):	
Width of opening of hopper	1¼ inches.
Angle of inclination of grate	38 degrees.
For Small Coal (passing through 1¼ inch mesh):	
Width of opening of hopper	1½ inches.
Angle of inclination of grate	36 degrees.
For Small Lump Coal (passing through 2 inch mesh):	
Width of opening of hopper	4 inches.
Angle of inclination of grate	31 degrees.
For Lump Coal:	
Width of opening of hopper	Fully open.
Angle of inclination of grate	31 degrees.

In Plate III is represented an improved grate which is in use in many factories. While the principle is the same as that shown in the one described, a comparison of the two plates will show considerable difference in construction. In this one, we have as a foundation two wrought iron supports, about 2x6 inches, running across the furnace, with the ends secured in the masonry. On these are laid either sliding perforated plates or a series of small grate bars. It has a length, from foot of step to furnace walls, of twelve to fourteen inches. These grate bars are generally laid flat, but in some cases the end next to the furnace wall is slightly raised. In perpendicular section these grate bars should have a triangular shape, the top being ¼ inch and the bottom $\frac{5}{32}$, and the distance between them at the top ⅛ of an inch. Below this perforated plate, or set of grate bars, there is a solid plate, as is shown in the plate. The grate bars themselves are often made moveable to facilitate the removal of any clinker that may be formed. In some instances this solid plate is several inches, or even a foot, below the grate bars or perforated plate, and the

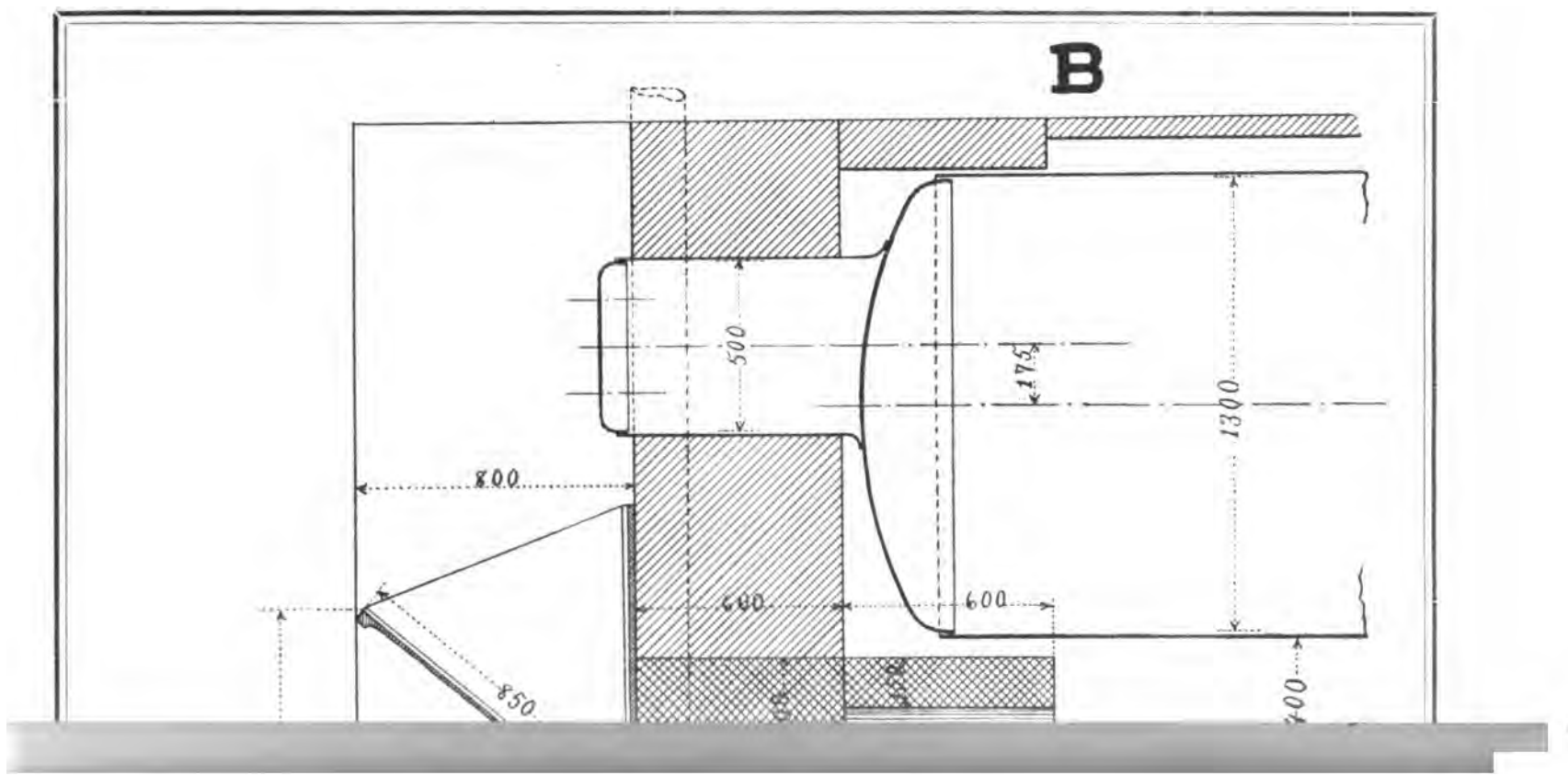
PLATE II.

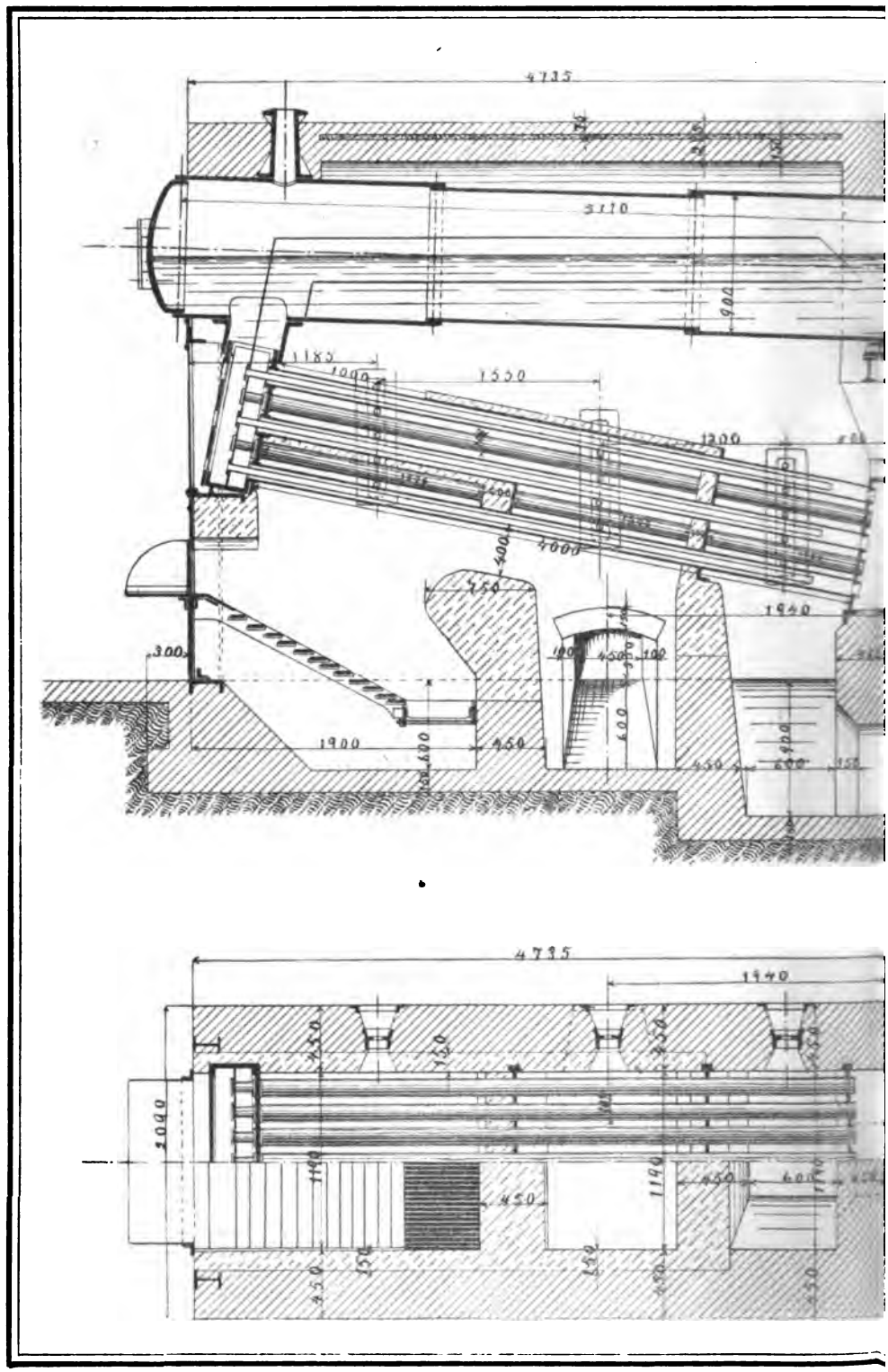


STEP GRATE FOR ORDINARY STEAM BOILER.

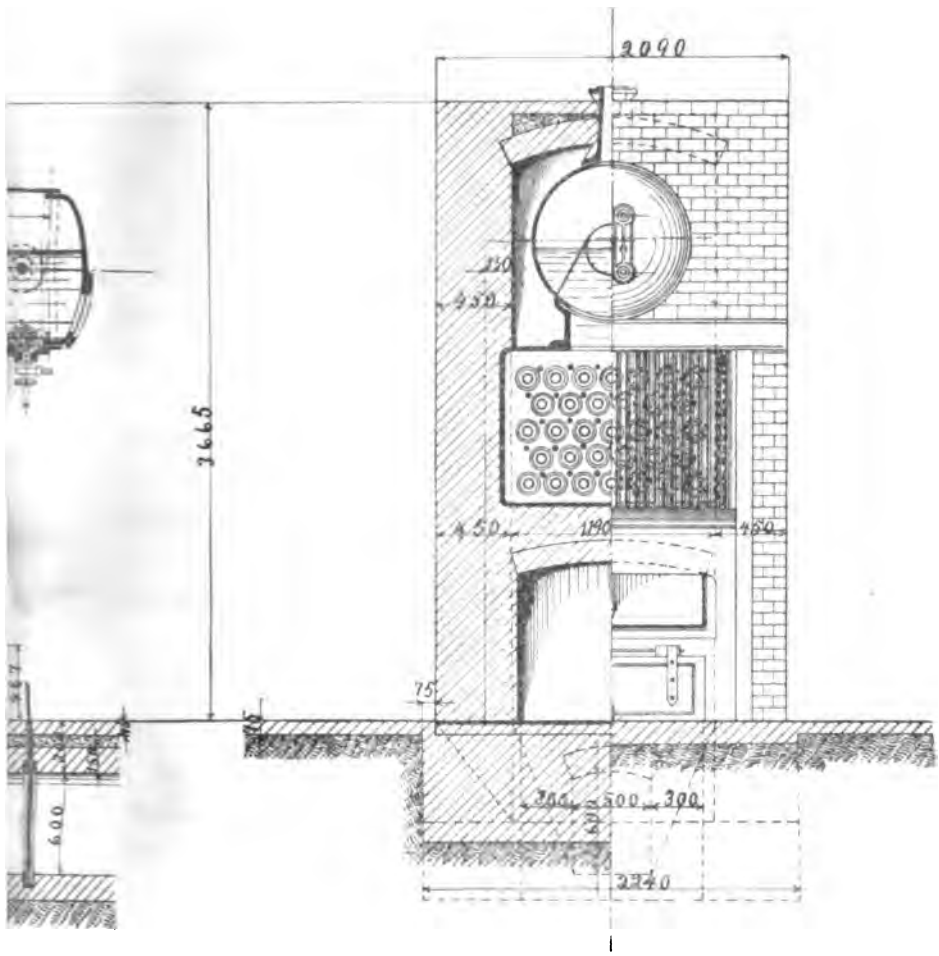
p. 56

PLATE III.

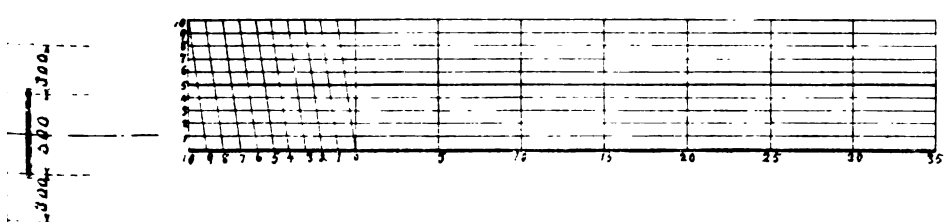




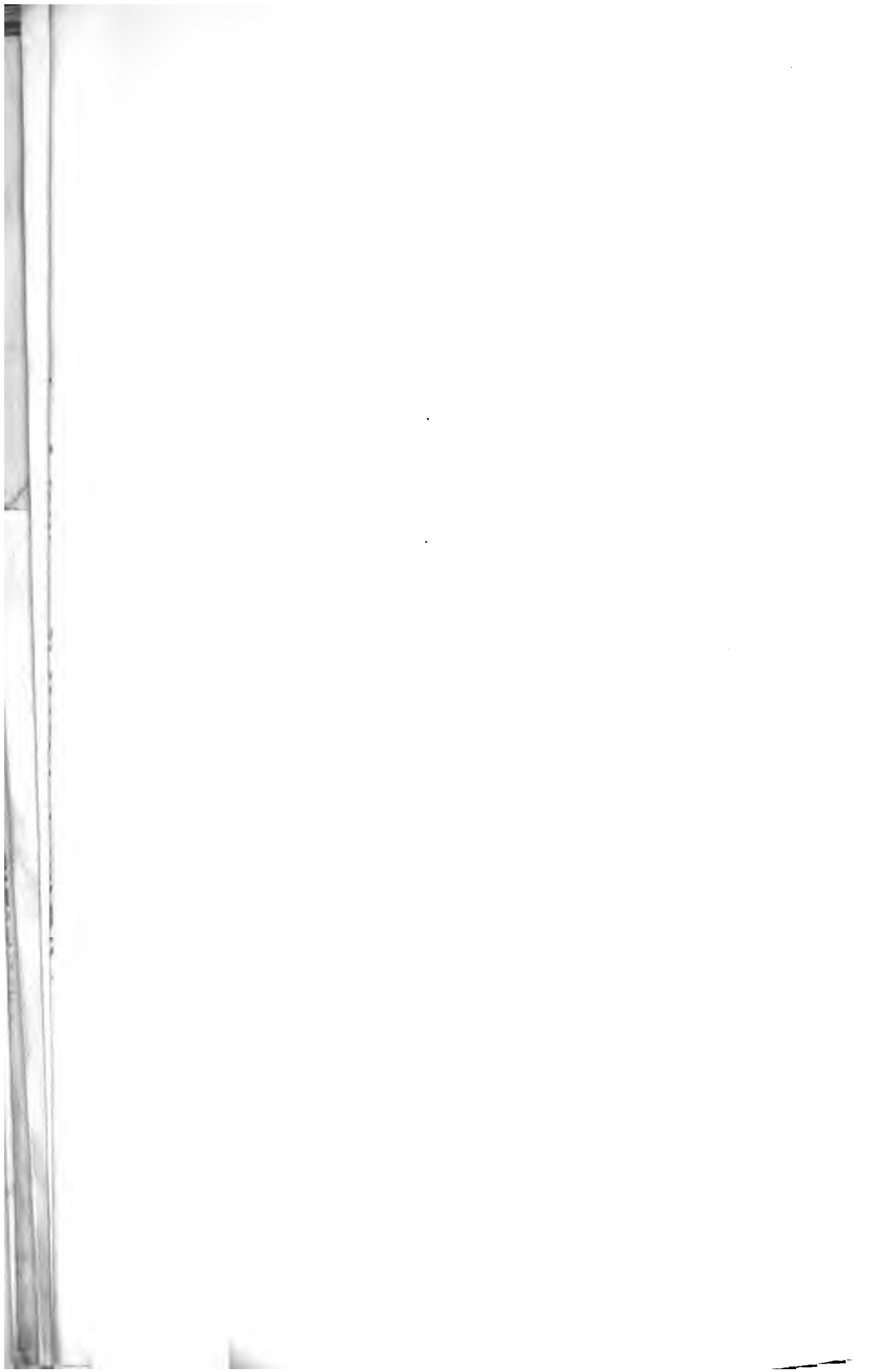
STEP GRATE UNDE



SCALE.



; SAFETY BOILER.



intervening space is closed by a door or damper. Springing from a suitable support above these small grate bars and resting against another support above are the iron string boards, which are similar to those already described. At the top of the step grate, and below the "T" beam against which it rests, there is a sliding gate by which the supply of fuel may be regulated or entirely shut off. Above this is the funnel or hopper, whence the fuel is fed to the fire, regulated by the sides of the opening at "a," which is determined by the position of the sliding gate.

The following figures give the details of the arrangement of this hopper as used for the different sizes of brown coal at Donawitz:

For Slack Coal No. 2 (passing through mesh ⅜ inch square):
- Width of opening of hopper..... 2½ inches.
- Angle of inclination of grate..... 40 degrees.

For Slack Coal No. 1 (passing through ⅝ inch mesh):
- Width of opening of hopper..... 2¾ inches.
- Angle of inclination of grate..... 37 degrees.

For Small Coal (passing through 1¼ inch mesh):
- Width of opening of hopper..... 3 to 3½ inches.
- Angle of inclination of grate..... 31 degrees.

For Small Lump Coal (passing through 1½ by 3 inch mesh):
- Width of opening of hopper..... 4 to 4½ inches.
- Angle of inclination of grate..... 29½ degrees.

For Lump Coal:
- Width of opening of hopper..... Fully open.
- Angle of inclination of grate..... 28 degrees.

In Plate IV is shown a step grate arranged under a safety boiler, using the same character of coal. This has only two sections of grate bars, and the space at foot of step grate is closed with flat bars as in Plate III.

From the descriptions given it will be seen that the step grate is in a measure self-feeding. The firing of a step grate requires less exertion than is the case with a flat grate, but as these step grates do not clear themselves of ashes by their falling through, it is necessary for the fireman to clear the space from time to time. The principal recommendation of the step grate is its great regularity in burning, and the fact that by a proper regulation of the draught the combustion can be rendered practically complete and almost smokeless.

These present the general principles in use in all such grates in Europe. Many patented appliances are used with them by various manufacturers, by which the feeding of the coal is regulated, and other methods of economizing labor provided. But, just as in this country, the flat grate is in general use everywhere, and the improved grates are the

exception; so there, the forms of step grates here illustrated are the ones in general use, and only occasionally is one of the patented grates to be found.

FLAT GRATES.

If, however, it is desired to use a flat grate, as is done with the friable and pulverulent brown coals in some parts of Germany, the grate bars are made thin and close together.

The grate shown in Fig. 4 is recommended for this purpose.* It has the following dimensions:

Length of bar	12 to 13	inches.
Thickness of bar at top	¼	inch.
Thickness of bar at bottom	5–32	inch.
Space between bars at top	⅛	inch.
Depth of bar	3	inches.

In addition to these plain forms of grate bars others are in use which, by the character of their upper surface and sides, are intended to secure the best results possible with slack of brown coal. Such grates are figured on Plates V, VI, and VII in connection with the use of brown coal for locomotive firing.

These various designs of flat grate bars have the further advantage of costing a very small amount in making a change from the old style bar.

The importance of a suitable grate for the successful use of brown coal is such that I have reproduced these drawings of several different arrangements which are in the most general use in Austria and Germany in order that the variations may be properly understood. The original drawings of all these plates, which are made to scale, are in the office of the Survey and are at the service of all those interested in their use. They have been in use so long that they are no longer subject to patent, and can therefore be used by any one free of cost in that respect.

There are, no doubt, American grates among the large number which have been patented and which have come into use in different localities some of which will prove suited to the needs of brown coal. An inspection of those here presented will give an idea of what is needed, and will enable our machinists and engine builders, if they prefer to do so, to select such American grates as promise success, and use them as they are or with such modification as may be found necessary.

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*Von Reiche, H. Anlage und Betrieb der Dampfkessel. Leipzig, 1886, pp. 129–135.

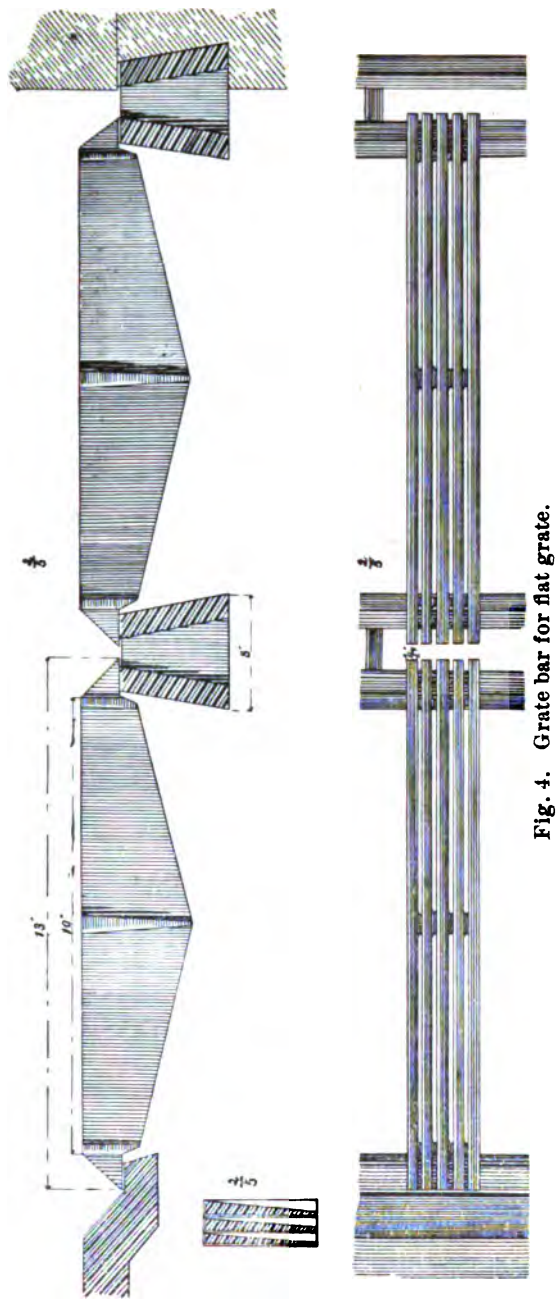


Fig. 4. Grate bar for flat grate.

RAW BROWN COAL FOR LOCOMOTIVE FIRING.

Railroad companies are the largest consumers of coal in our State, the daily consumption being many thousand tons. At the present time, with the exception of the coal from Laredo, Eagle Pass, the Texas and Pacific mine at Thurber, and the Wise county mines, their entire supply is brought from outside the State. The coal now being used is mostly from Alabama, Arkansas, Indian Territory, Colorado, and New Mexico, and the distance which it must be hauled adds greatly to its cost, even to the railroads themselves.

Almost every one of the principal railroad systems of the State cross the deposits of brown coal at some point on their line, and some of them are built directly upon them. If therefore it be possible to use this fuel on the locomotives effectively, and at the same time economically, it must necessarily result in a marked reduction in their fuel account, by reason of the cheapness with which the brown coal can be mined.

Brown coal has been used in the locomotives of Austria and Italy for many years, and, in many parts of Bohemia, in spite of the heavy grades and long trains that are common, no other fuel is used.

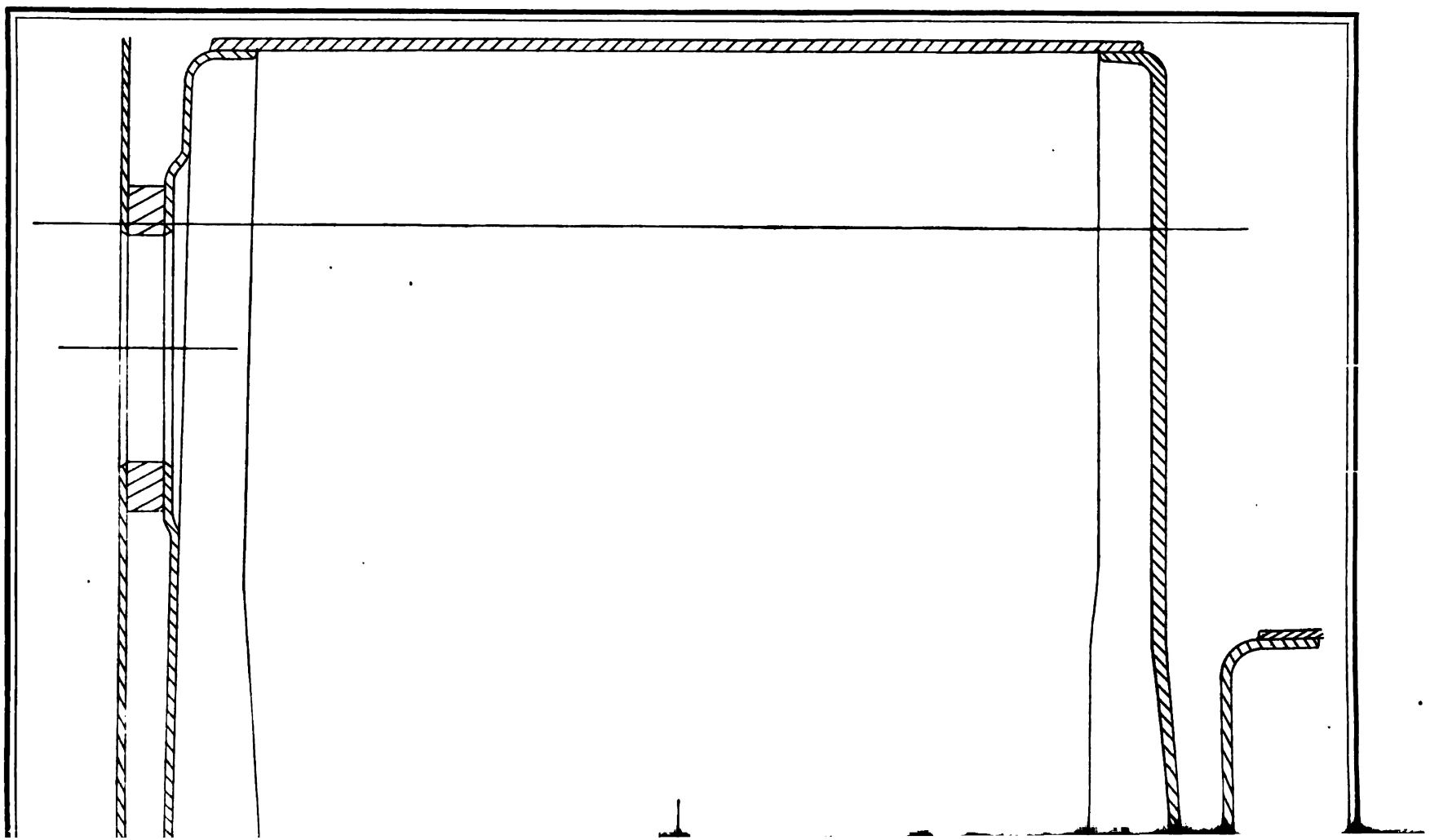
When brown coal in the form of briquettes is used for locomotive firing, little if any change is necessary in the locomotive fire box, the principal point to be watched being to secure a proper draught. But when we come to the use of raw brown coal in locomotive fire boxes, we must again take the character of the fuel into consideration and provide a suitable fire box, grate, and draught in order to secure such efficiency as will make it possible to use it. Many years of actual use of this fuel in Austria have demonstrated that locomotive firing with brown coal is not only possible but has resulted in a great decrease in the expense of heating and, as already stated, is in general and exclusive use to-day on many of the larger railroads of Bohemia.

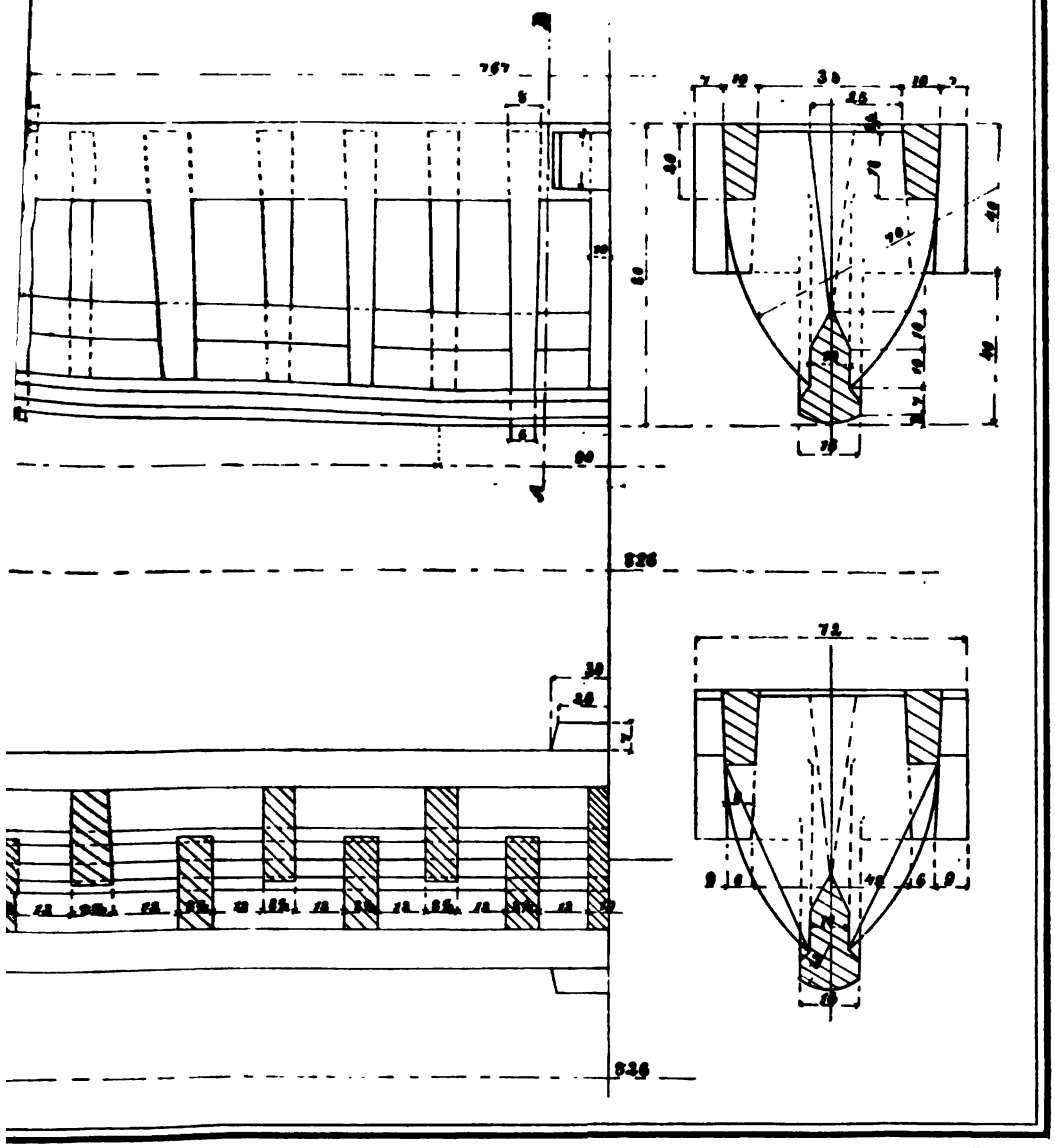
Through the kindness of Professor Leopold Ritter von Hauffe, a member of the Aulic Council, and Professor Dr. Johann Oser, of the Institute of Technology of Vienna, the Wiener Locomotiv-Fabrik Actien Gesellschaft, who manufacture locomotives for using brown coal as fuel, have furnished me with drawings of the different fire boxes, grates, and smoke stacks manufactured by them for this purpose. Some of the drawings are reproduced in the accompanying plates, which as usual give detailed sections and measurements.

LOCOMOTIVE FIRE BOX.

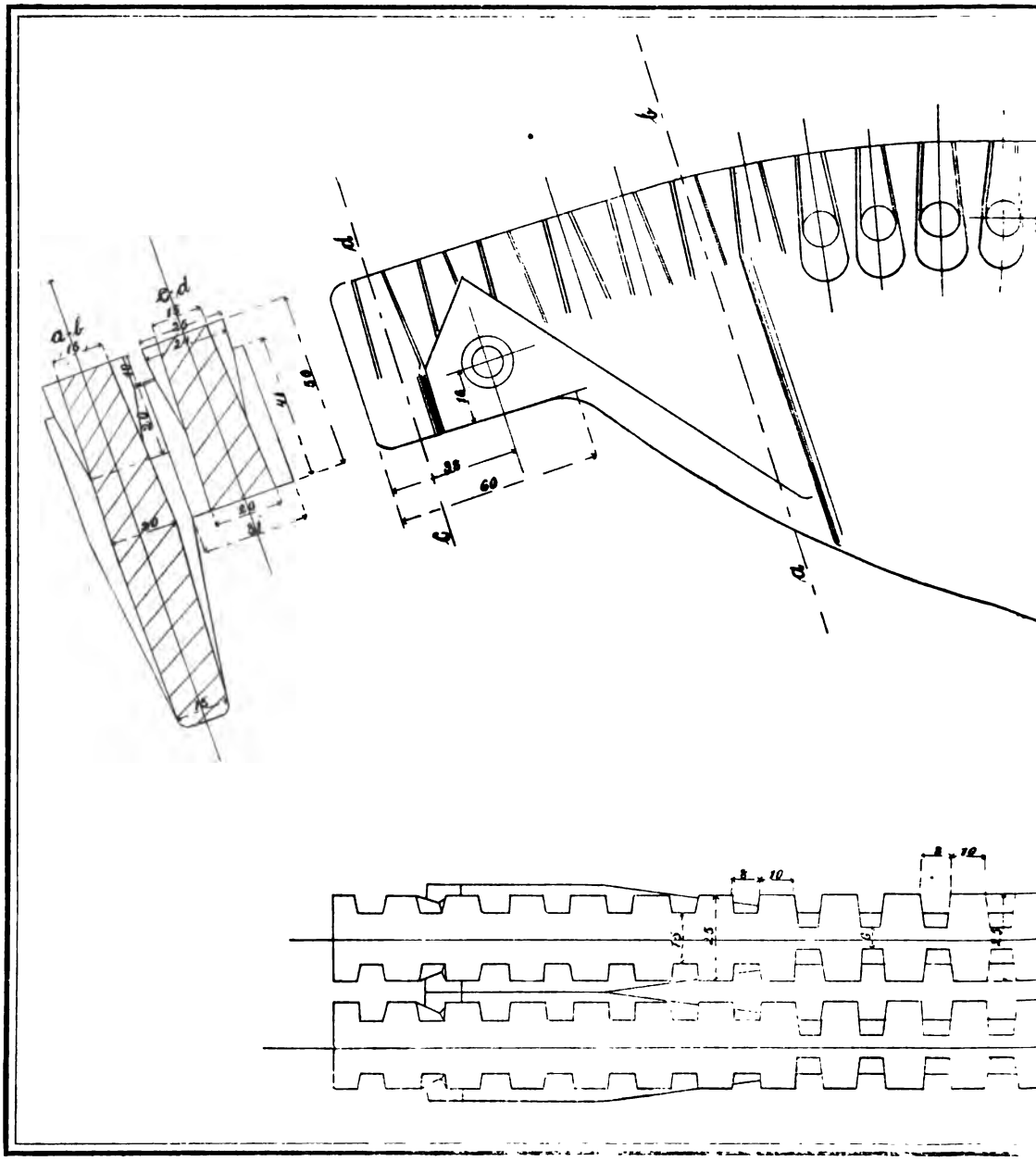
P. 80

PLATE V.



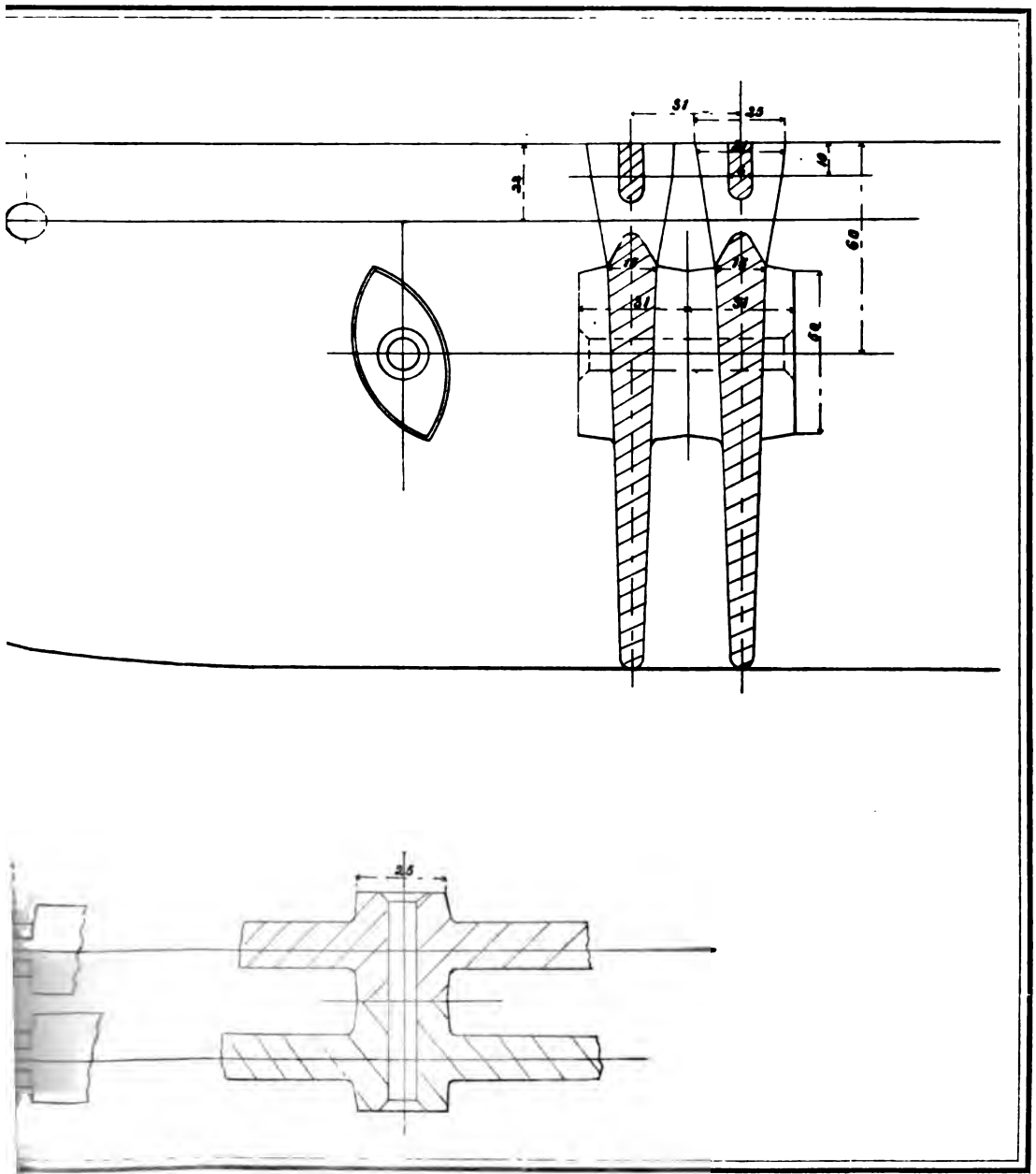


'E BAR.



GRATE BAR FOR

III.



TIVE.

p. 60

For medium lump coal (three to four inches) ordinary flat grates are sometimes used with wrought iron bars having a thickness of $\frac{3}{8}$ inch and spaces of $\frac{1}{4}$ to $\frac{3}{8}$ inch. The smallness of the space being determined by the cleanness of the coal and its freedom from clinker. The spaces therefore must be regulated in every instance by the character of the coal to be used. The narrowing of the space prevents loss of coal, and is desirable whenever it can be done without the interference arising from too heavy an ash or clinker, and the proper proportions are only obtained by trials of the various coals which it is expected to use. As this is the practice in many places with the bituminous coals now in use, it presents no additional difficulties. The dimensions found most advisable on the Dux and Bodenbach railway, after exact trials, was both for bars and spaces 10 mm. or $\frac{3}{8}$ inch. This is of course only for use with lump coal, and not where it is found preferable to use small coal or slack. For this purpose the special heating arrangements which are here given have been designed and are giving complete satisfaction.

Plates V, VI, VII, represent the arrangements as used on numerous freight engines. They consist in the main of three parts:

1. The flat grate.
2. The upright grate.
3. An arch of fire brick over the grates.

The Flat Grate.—This is constructed with single cast-iron grate bars, which have an open dice-shaped surface, which is shown in Plates VI, VII. This peculiar shape is designed to prevent the small coal from falling through, and at the same time to furnish sufficient openings for proper access of air. A variation of this grate bar is shown in Plate VIII. These grate bars are set in two rows in supports of suitable construction, the details of which are given in the sections.

The upright grate, which is of the Nepilly system, serves to convey fresh air over the coal. The air enters through the spaces beneath the screens, is thoroughly mixed with the heated coal gas, and secures a perfect and practically smokeless combuston. In this grate it is also highly important to have the bars and spaces of proper dimensions, so that while there is sufficient air to secure complete combustion there may not be so much as to cause any cooling of the tubes. The cost of attaching this arrangement to ordinary engines is very little, but the difficulties to be overcome have been so great that in Austria its use has been discontinued,

as it has been found possible to secure almost as good results by use of the fire screen.

The fire screen or arch, which is built of wedge shaped fire brick, is used to secure the heating of the air as it enters through the grate and the preservation of the lightest dust coal in a quiet position on the grate. This arrangement of the arch is absolutely essential to the burning of small coal. It has been used in England for many years for this purpose, and its use as here recommended will render possible the satisfactory burning of every sort of brown coal. By throwing the flame backward, it produces a more even heating of the surface of the fire box, and by checking the rapid flow of the burning gases extracts from them a greater amount of heat. The length of the arch should not be so great, nor its inclination at such an angle, as to hinder the proper spreading of the coal on the grate surface. The arch, as here constructed, protects the boiler-head from the cold air, and thus prevents some loss of heat from the tubes.

The first illustration (Plate VII) gives a longitudinal section of the fire box, showing the two lengths of grate bars and the fire brick arch, while the figure below it gives a view of one-half the surface of the flat grate. The second illustration gives cross sections, showing both the front and back of the fire brick arch and the grate bars, and the figure below it shows the general arrangement of the Nepilly grate, if used. The details of the grate bars and their supports are fully given in the cuts.

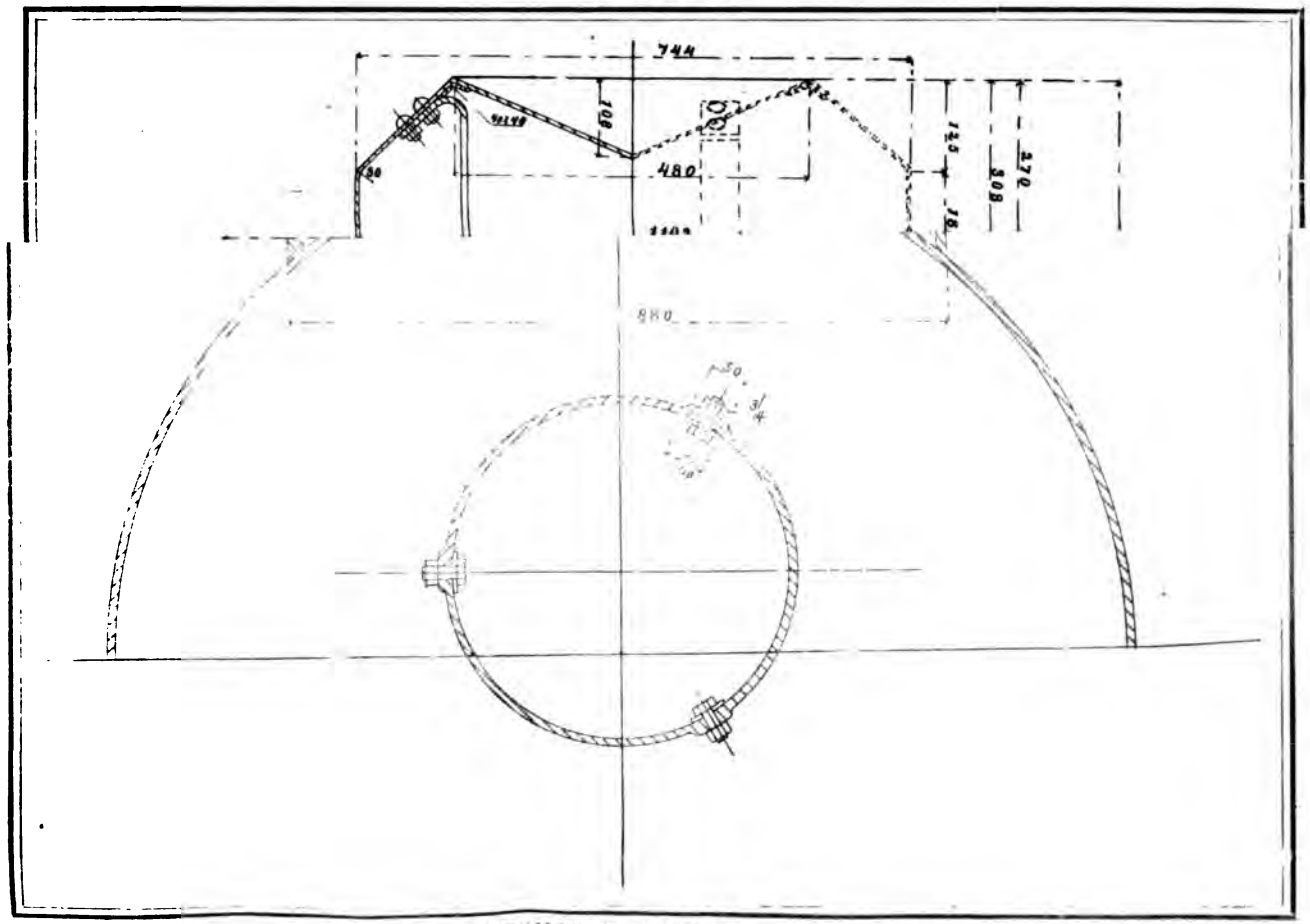
The third illustration gives a longitudinal section of fire box without fire brick arch, and below it a grate of somewhat different pattern to the one described, details of which are also given in the accompanying plates.

Still a third pattern of grate manufactured for using brown coal on locomotives is figured in Plate VIII. It was furnished by the Sachsische Maschinenfabrik, Chemnitz.

Two smoke stacks or funnels are figured in Plates IX and X, which are those of the Vienna Locomotive Works. These are designed to act as spark arresters where small brown coal is used, and are in use on many of the Austrian railways.

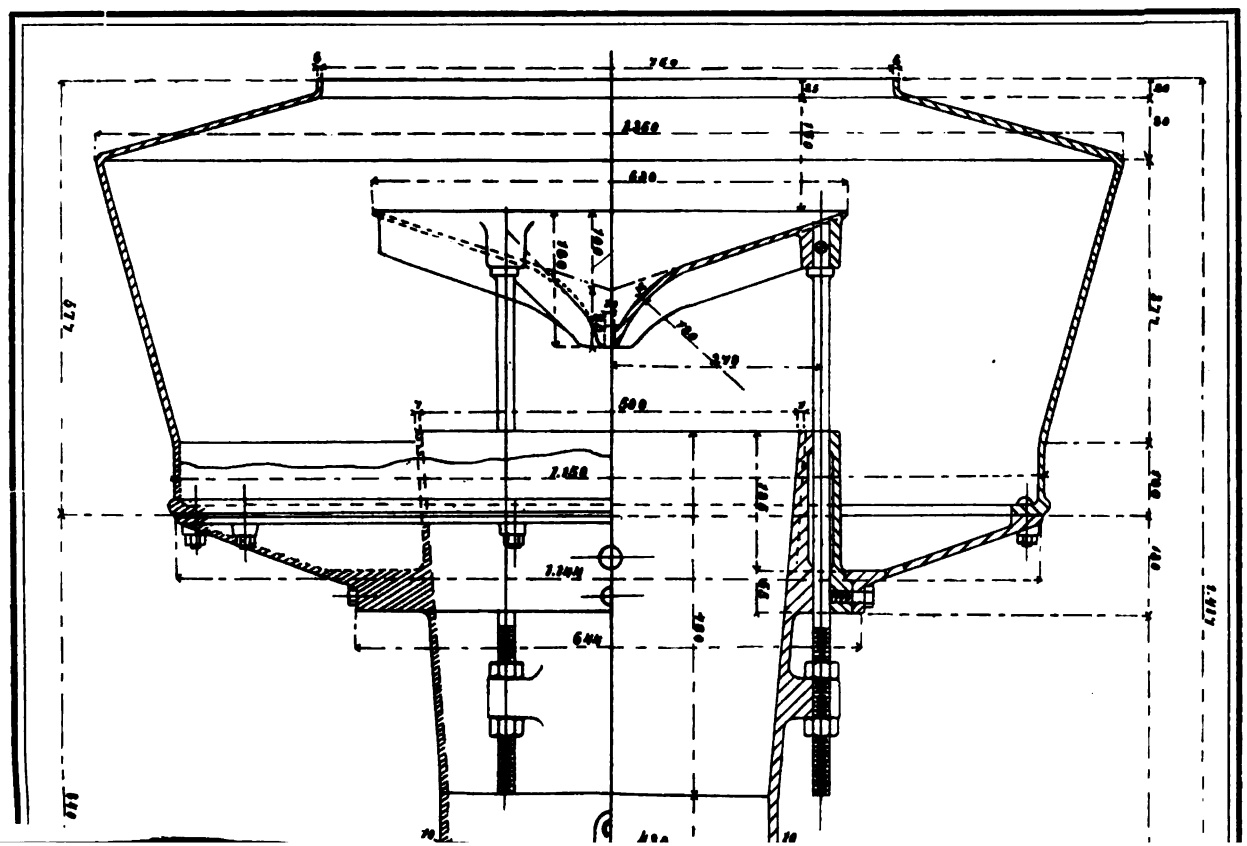
Much of the success which has attended the use of small brown coal of this kind on Austrian railways has been due to the care and good will of the firemen themselves.

PLATE IX.



LOCOMOTIVE SMOKE STACK.

PLATE X.



According to the statements made me by the Vienna Locomotive Works, the expense of firing locomotives with small coal, as is being done at present, shows a clear saving over the same firing with larger coal, which was in vogue eight or ten years ago, of forty to fifty per cent. If to this saving we add the difference in the cost of bituminous coal and brown coal in this State, what other argument can be needed to enforce the use of this material on our railroads?

The drawings from which these plates were made are on file here, and the originals can be examined or tracings taken from them by any persons needing them for experiment or manufacturing purposes.

GAS FIRING.

The use of fuel in a gaseous form had already attained a firm footing before the discoveries of natural gas in this country. The rapid development and great number of applications of this fuel where it has been found in sufficient quantities, and the successful operation with gas artificially prepared to supply its lack where it was not found, have demonstrated fully the desirability of such a fuel.

The manufacture of producer gas for fuel is carried on in two different ways. In the first, which is here represented by the generators at Donawitz and Teplitz, we have the gas which is formed by access only of such an amount of air as comes to it through the draught, and which might be termed an "air gas." In the second form, which is illustrated by the description given of another producer, we have a forced draught, and also an admixture of steam in the generator.

In Europe, gas produced from the earthy and other brown coals is used in all metallurgical operations and many kinds of manufacturing requiring a high heat. These include the manufacture of wrought iron and of steel by the Bessemer and Martins processes, and rolling of iron and steel; reduction of certain ores; cement burning; burning lime and gypsum; bricks and sewer pipe; potteries and glass works; chemical manufactures; and, in short, any and all branches of manufacture in which it has been found practicable to use a fuel of gaseous nature.

The generator necessary for the proper and economic production of gas from brown coal varies somewhat with the use which is to be made of it, but in many producers the brown coal can be used with little if any alteration.

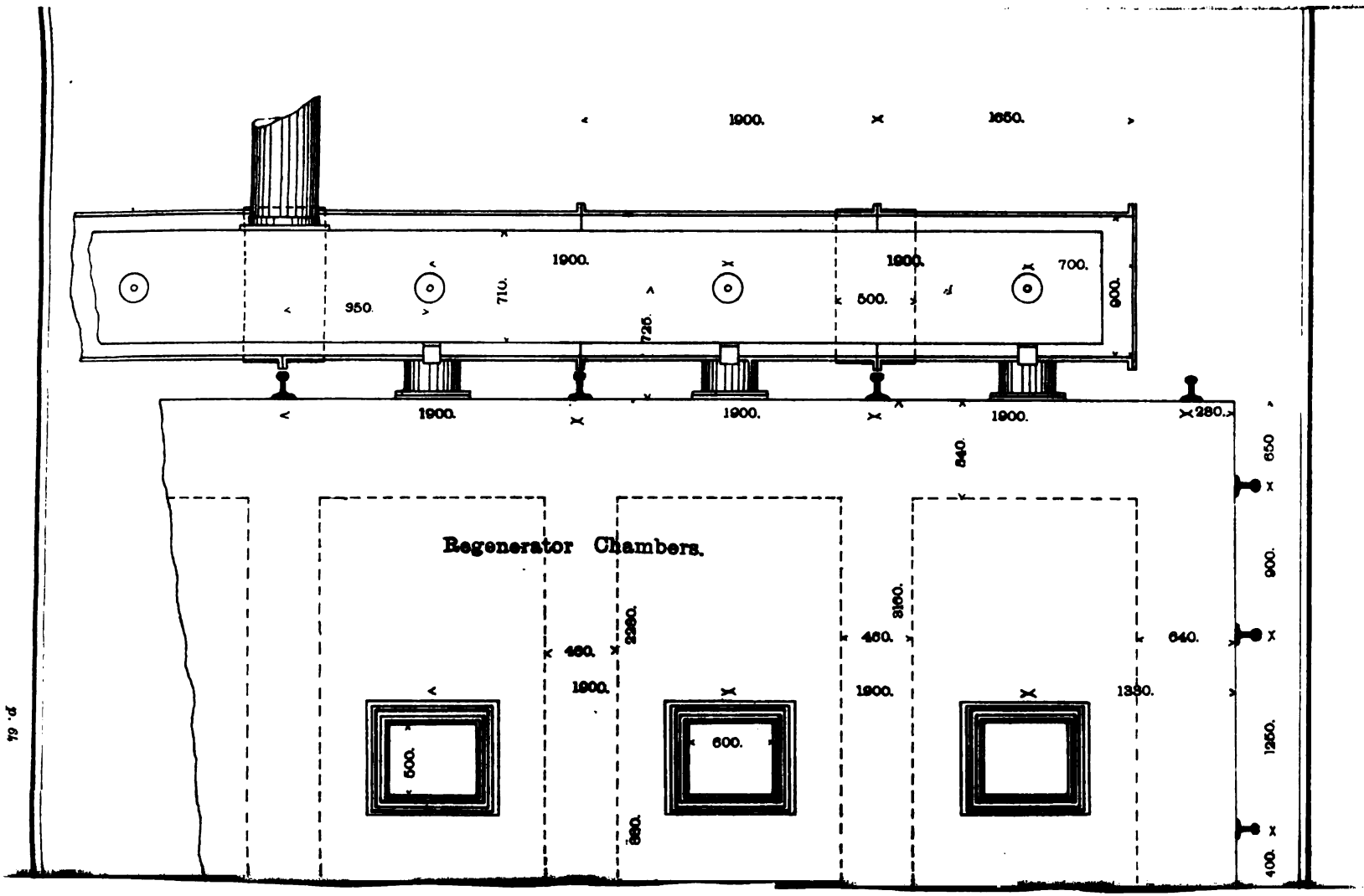
In Bohemia, at the steel works and rolling mills of the Teplitzer Walzwerk und Bessemerhütte, the producers illustrated on Plate XI are in use for producing gas from a brown coal very closely resembling the ordinary product of the mines now open in the brown coal area in Texas.

These generators consist of a chamber lined with fire brick, having a step grate of ordinary construction to which the coal is fed through funnels which can be hermetically sealed to prevent the escape of gases. The amount of gas produced can be regulated to a certain extent by the amount of air allowed to pass through the step grate. The gas produced finds its way through the exit tube to the hydraulic main, and from here through regenerators. In some instances the hydraulic main is omitted and the gas passed directly to the place at which it is to be burned, or is carried through regenerators as before. Such is the general description of the producers used at the larger iron works of Styria and Bohemia, by means of which the small brown coal is made to furnish sufficient heat for all their operations in the conversion of pig iron into steel by both the Martins and Bessemer processes or into wrought iron and the rolling of these materials into every variety of manufactured metal.

The first illustrations (Plate XI) are two views of the Teplitz generator from the front. The section A B is taken vertically through the feeding funnel, showing front view of treppenrost or step grate, feeding funnel and lower part of exit pipe.

C D is made at right angles to this and gives the construction of the step grate, the feeding funnel, the exit tube, hydraulic main and connection with regenerator chambers.

The feeding funnel in this producer is movable, and the distance of its lower margin from the top of the step grate is determined by the size of the coal which is to be fired. The cover is sealed with a water joint. The entire construction is so clear in the drawing that a description is scarcely needed. The brick work has the usual chambers, and the inside wall of the furnace is lined with fire brick. The exit pipe is supplied with a valve by which the flow can be stopped when desired. These generators differ from the ones in use at Donawitz, in Styria, in the movable feeding funnel and in other particulars readily noticeable by a comparison of the drawings in Plates XI and XII. These represent the general principles of all the gas generators without blast, and can be used with or without the regenerating ovens, as may be required. The sim-


1900.
1650.
1900.
1900.
700.
950.
710.
500.
900.
725.
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1900.
1900.
280.
840.
650
900.
1250.
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Regenerator Chambers.
460.
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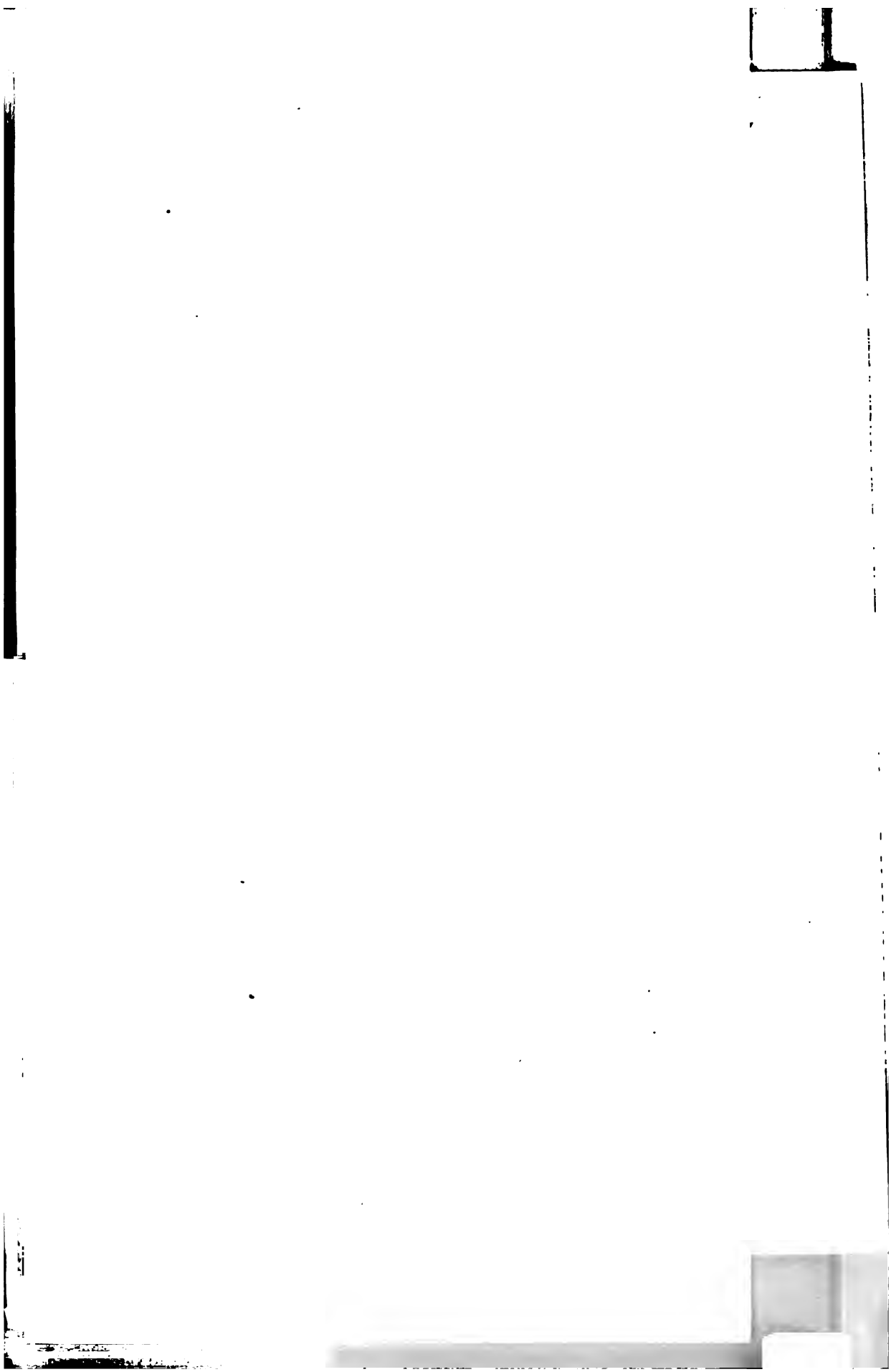

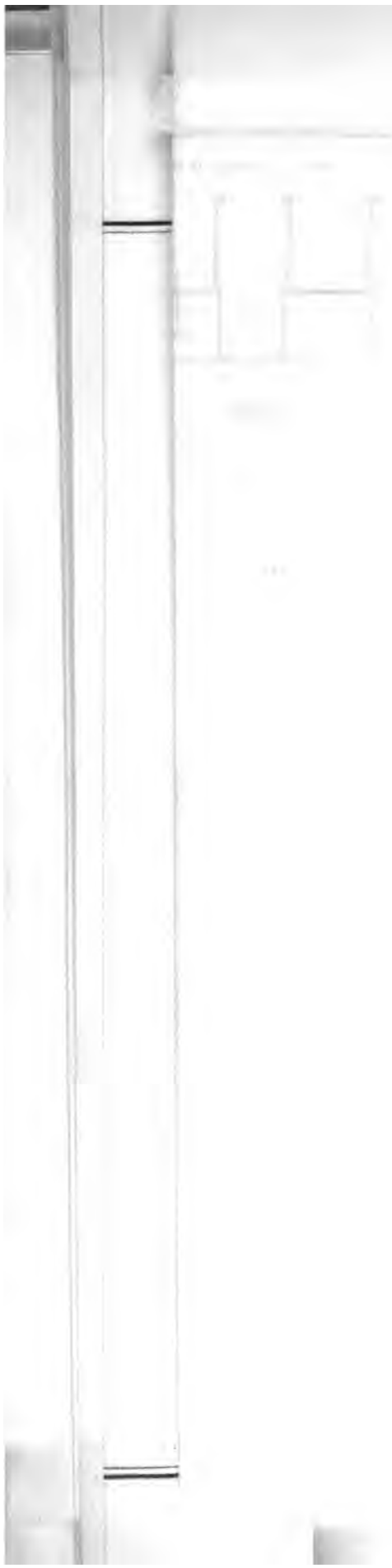

plicity of their construction, durability and ease of working recommend them most highly for the purposes for which they are intended.

For other purposes, however, many other forms of generators are in use. Some of these are patented and can only be used subject to the rights of the owner of the patent. The ones figured are in no way subject to patent and are therefore free for all to use.

GAS PRODUCERS WITH BLAST.

The general method of constructing gas producers with blast with step grate for firing is shown in Plate XIII, which represents one of a battery of such producers in use at Donawitz.

There are also many other forms of producers of this class, both in Europe and America, which may utilize this fuel.

The use of gas in firing pottery, brick, drain tile, and other clay products, has received much attention, and many factories are operated with it throughout Europe. The same is true of glass factories, cement works, lime kilns, chemical works, and indeed all industries to which gas fuel is applicable, and in all of these the gas produced from brown coal furnishes their constant supply of fuel.

Brick clays and fire clays are often found in close proximity to the brown coal, and the manufacture of bricks, fire brick and tiles, at an extremely low price, is thus rendered practicable, and a great number of mines have brick yards in connection with them by means of which they are enabled to make use of all their coal, even what would otherwise be refuse.

At one of the larger brick works on the Rhine the experience from a trial of several years proved that firing with a mixture of brown coal briquettes and raw brown coal gave better results in actual work than stone coal alone, stone coal with briquettes, or stone coal and raw brown coal, and at the time of my visit works were just being completed for briquetting their brown coal for use in this manner.

In brief, if I may be again allowed to repeat it, the use of raw brown coal, either in direct or gas firing, has been proved not only possible, but economical as well, for all industrial purposes for which bituminous coal is applicable.

ILLUMINATING GAS.

Certain varieties of brown coal produce gas of very high candle power; thus the Reichenau deposit furnishes a material which affords a gas of thirty-five candle power and is widely used as a gas enricher, and the schweelkohle of the province of Saxony furnishes on distillation a heavy oil, which is used in many of the smaller towns in the manufacture of illuminating gas.

Teplitz, in Bohemia, is lighted by a gas made from the brown coal of the vicinity, having originally an illuminating power of seven to nine candles, enriched with a small percentage of Reichenau brown coal to produce twelve to fourteen candle power. The retorts and plant in general have nothing in anywise different from the plants for the manufacture of gas from stone coal, except that the smoke stack is removed a little distance from the benches of retorts, and the furnace gases, after having done their duty in the volatilization of the gases from the material in the retorts, are conducted through a number of canals situated below a brick floor over which is spread the brown coal for the next charge. This waste heat is thereby made to evaporate the excess of moisture from the brown coal and it is placed in the retort practically dessicated. The gas gives perfect satisfaction, and the coke is separated by sieving, the finer material being sold to the zinc reduction works, while the coarser part is sold in Teplitz for various uses. One hundred kilos of brown coal yield 17.5 cubic meters of gas—about three cubic feet per pound.

In Italy the experiments made for producing illuminating gas from Italian brown coal have been extremely satisfactory, and show that it can be done not only to the entire satisfaction of the consumers, but at a much greater profit to the producer than is possible with bituminous coal.

In September, 1891, the city of Spezia entered upon some experiments, being incited thereto largely by the patriotic motive of assisting in bringing into use the deposits of brown coal of the neighborhood in place of the coal imported from England. These experiments included not only the production and sale of illuminating gas, but a briquetting of the resulting coke for steam purposes, according to the method proposed by Messrs. Stacchina, known as the Sapori patent. So successful was the result that a special official report* was published concerning it, giving the

* Relatione ufficiale in ordine agli esperimenti sulla lignite per la produzione del gas-luce. Spezia, 1892.

details of the experiments, cost and character of products, returns from their sale, and a general discussion of the subject.

There were present during the experiments representatives of the Italian governmental bureaus of Mines, Agriculture, Industry and Commerce, of the Inspector General of Railroads, and of the Navy, mining engineers, and scientists, including Sir C. Capacci, the Italian authority on brown coal.

The experiments began on the 27th day of September with a thorough test of the New-Pelton coal and the determination of its illuminating power as a standard of comparison for that from the brown coal. The experiment with brown coal began on the 28th and continued through the 29th, during which time 29.04 tons of brown coal were subjected to destructive distillation. This was of the following character:

4 tons lump coal.

20.04 tons small coal.

5 tons slack.

The distillation was effected in five benches of retorts, three of which were of ordinary pattern, containing in the aggregate fourteen retorts, and the other two were of the Horn system with seven retorts each. The retorts were completely cleared of the coke remaining from the coal before the brown coal was introduced. The method of production of gas from bituminous coal was followed without deviation in quantity or quality of fuel used in order that the heat of the furnace might be constant and equal. Under these conditions a retort charge of two hundred and seventy pounds of bituminous coal required six hours for distillation, while one of brown coal weighing two hundred and thirty-four pounds was completed in four hours.

The amount of gas produced from the twenty-nine tons of brown coal was two hundred and sixteen thousand feet, or a little under seven thousand five hundred feet per ton. Careful photometric measurements of the gas produced from brown coal on the 28th and 29th, and of that made from bituminous coal on the 27th and 30th, showed the illuminating power of the brown coal gas to be nine-tenths of that of the coal gas, or more precisely, in the relation of 89.14 to 100. The gas produced was used for lighting, in Otto gas engines, and for producing steam, and in each and every instance gave as good satisfaction as the coal gas, and nowhere was there any dissatisfaction found among the consumers. From

the report it would appear that the briquetted fuel from this particular trial was not so satisfactory as was hoped for, on account of a much larger percentage of ash than was expected from an analysis of the coal, and much more than was found in other brown coal cokes, the manufacture and use of which have fully proved their adaptability for steam, industrial and household uses, when prepared in this manner.

The brown coal used in these experiments was that of Casteani, which, according to Capacci, has the following composition in water-free specimens. Analyses by E. Bechi:

	First Quality.	Second Quality
Volatile matter	37.60	39.00
Fixed Carbon	61.85	53.68
Ash	.55	7.32
Sulphur	6.12	1.00

Moisture varies from 1.25 to 17 per cent in different analyses. Capacci gives 8 per cent for second quality.

CHAPTER IV.

BROWN COAL AS FUEL—continued.

BROWN COAL IN IRON SMELTING.

Like all other proposed uses of brown coal, that in connection with the smelting of iron ores has been the subject of long and careful experiment, and while it has not been found possible to entirely supplant the use of bituminous coal or coke with brown coal, it has been clearly proven by actual operations on a commercial basis, which have extended over a number of years, that it is both possible and profitable to employ brown coal as a part of the fuel used in such work.

The experiments have been directed both toward the production of a coke from brown coal which would be serviceable in the iron furnace, and to the use in the furnace of the raw brown coal itself.

The first of these proceeded on the understanding that if a coke could be produced from brown coal containing no greater amount of ash than that of the stone coal, of sufficient hardness to support the furnace burden, and in large enough particles and porous enough to permit the proper passage of the blast and gases, there would be no difference, practically, in smelting iron with the two.

The other experiments are based on the experience gained in smelting ores with raw bituminous coal, and have proved very successful.

Many attempts have been made to secure a good coke from brown coal, but so far it has not been found practicable to produce coke of sufficient size and low enough in price to render it available for this use. Ordinary brown coal when submitted to the coking process comes from the oven as a powdery coke, few fragments being over a quarter of an inch in diameter. Some of the lignitic varieties, however, can be charred, and yield a kind of charcoal which is suitable for the blast furnace, and are so used.

Prof. Kupelwieser, of the Mining Academy of Leoben, who has given the subject much attention, and who, by his experiments and his acquaintance with those of others working to the same end, is most capable of

giving a correct opinion on it, has written an article* concerning this use of brown coal, the substance of which, supplemented by other information received from him personally and by my own observation, is used as the basis of the following statements:

When the varieties of brown coal which are of compact structure and conchoidal fracture, such as the pitch coals or glance coals, are charred or subjected to the coking oven, a coke is usually produced which is in small cubical pieces, the largest of which is rarely larger than a quarter of an inch in diameter. These fragments are hard, compact, and only slightly friable, and if it were possible to produce a similar coke in pieces of sufficient size it would go far toward solving the question. As yet this has not been done.

Where lignite, or that form of brown coal which still shows the woody structure, is charred, it sometimes forms a good charcoal, but often produces thin leaves, which, while they may be of small size, are quite hard and firm. This tendency to split up is much less in the lignite showing a knotty structure than in that having a straight grain. When the lignite forms a good charcoal it is of course serviceable, but the smaller fragments are open to the same objections as those from other brown coals.

Attempts to coke charred brown coal with good caking coal have been made repeatedly, in order to secure thereby the coke in larger fragments, but the practicability of this process for this purpose is not fully decided and the possibility of a suitable production depends largely on whether a good caking coal for use as a bond can be procured at a sufficiently cheap price. The brown coal must be finely powdered, intimately mixed with the caking coal, and coked at high heat. The manipulation is rather complicated, and the coke produced in this way still remains somewhat friable, on which account it would be necessary to erect a coking plant at the place of use, that is, in the vicinity of the blast furnace.

The objection to the use of fuel of such small size in the blast furnace seems to be due to the fact that the zone of fusion alters its position in point of density in accordance with the size of the materials used in the furnace. That is to say: if in a given furnace which is being run with

*Studien über die Verwendung der Braunkohle bei der Roheisenerzeugung (Verhütting der Eisenerze), 1881.

coke for fuel, the materials be charged in smaller fragments, and the furnace charge and the blast be respectively of the same height and pressure as with the other charges, then the tension of the gas in the furnace will become greater and greater, in proportion to the smallness of the fragments. If the other conditions remain unchanged, then the increase of tension of these gases will prevent the proper passage of the blast, and the amount of air and mixed gases passing through the furnace will become less and less, until a certain limit is reached, at which the burning of the fuel is completely stopped and the process is entirely arrested. This phenomenon will always make its appearance as soon as the grain of the fuel and the ore is so small that the uniform penetration of the blast through the zone of fusion becomes impossible; and this will be the same whether we use with the powdered ore, small charcoal, small coke, or coked brown coal in small pieces.

Since the coke of brown coal has this disadvantage of small size, and is subject to further pulverization in transportation and even in charging into the furnace, it seems to be much more advantageous to charge the brown coal raw. This offers the following advantages: The cost of coking is entirely saved; the porosity of the charge is much greater—at least until the coal crumbles down; and the gases present are richer and more valuable. It is not considered necessary to charge the brown coal in large lumps. Well assorted medium lump coal which has been freed as far as possible from dust, impurities and hygroscopic water, will give excellent results.

In order that the objections which have been mentioned may be overcome, the following methods are suggested by means of which brown coal in its raw state or the substances produced by coking it, may be made to replace a large proportion of the fuels now used in the production of pig iron.

First. To keep the zone of fusion porous under conditions which are otherwise similar to the present, a greater pressure of blast may be used. While it is true that the tension of the gases certainly increases with the pressure of the blast, it is also a fact that a part of these gases would be forced through the zone of fusion, and would thus serve to render it somewhat porous. If, however, this blast pressure is rendered too high relatively for the other conditions, and the mixture of gases can not penetrate the zone of fusion uniformly, it would result in the gases

forming canals where the resistance was least, and rushing through them without permeating the entire section of the zone of fusion. From the formation of such canals it would also happen that the outflowing gases, acting upon the ore, would become much richer in carbonic oxide, and would therefore form an easily explosible mixture of gases, which might lead to many inconveniences. It is necessary, therefore, that great care be taken that the pressure of the blast be never increased so far as to permit the formation of such canals.

It is also highly recommended that the blast should be distributed with the greatest possible uniformity over the entire section of the furnace, and that in charging the greatest care be taken to lessen the possibility of such canals being produced in the furnace. With these restrictions, since an increase in the pressure of the blast could be made up to a certain degree, it appears advantageous to work as nearly as possible to this limit in order to be able to use the advantage which may be derived from the strong blast, without being injured by its disadvantages.

Second. Another means of rendering the zone of fusion porous is found in a small alteration in the size of the material which it is proposed to work. In mining, burning, and roasting the ores, care can be taken that they be not made too small, and that not much fine ore or dust be used in the work. Having the grain of the ore uniform, and of not too small size, will aid essentially in keeping the zone of fusion porous and uniform. Such conditions seem to be easy in the smelting of magnetites and hematites, but greater difficulties are to be overcome in the working of siderite and limonite ores. With these ores, the briquetting of the ore itself seems to be of some advantage, providing expense will permit it, if by this means a homogeneous mixture of equal sized single fragments can be obtained; for thereby the use of a larger mixture of cheaper brown coal will be allowed.

Third. The form of the furnace has also a great influence upon the possibility of using brown coal and the quantity that can be used. In the determination of the form of the blast furnace there are two considerations which are somewhat difficult of accomplishment in the same structure. If raw brown coal is burned it is necessary that the furnace be provided with a comparatively large reduction chamber, the size of which can only be lessened if the hot ores are charged, which charge will assist in the preparation of the fuel. The second consideration is that the furnace be not built too

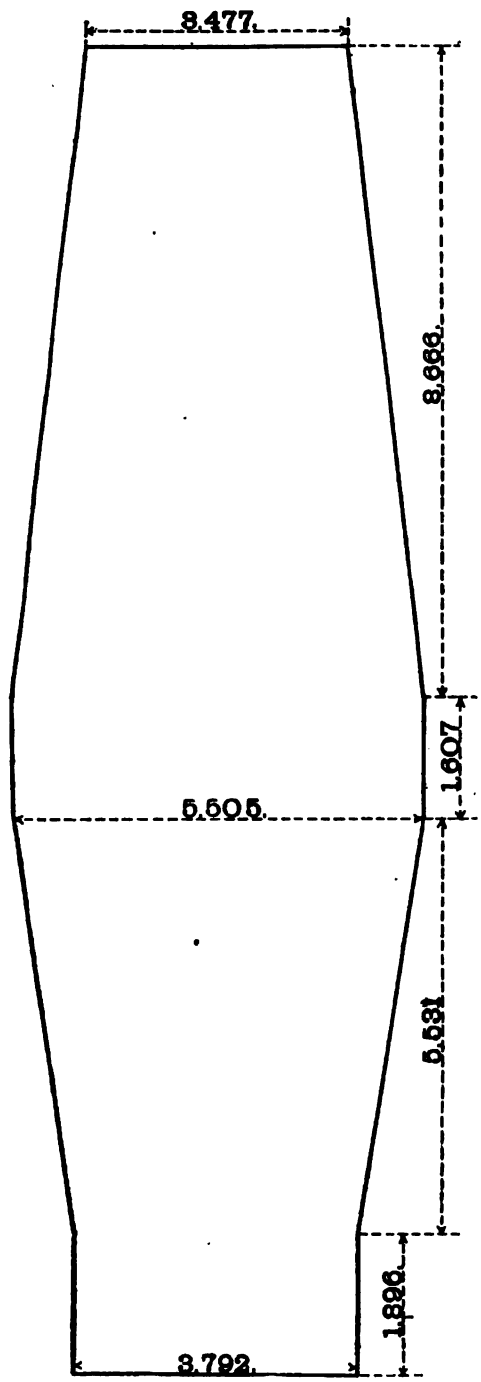

Fig. 5. Iron furnace at Zeltweg.

high, lest the zone of fusion be too thick. The running of blast furnaces with bituminous coal and light friable anthracite at many places has proven that high furnaces are not practicable for this purpose.

Under existing circumstances, therefore, the most promising outlook for the employment of brown coal in iron smelting would appear to be its use in the largest possible proportion with stone coal coke in the blast furnace process, and as producer gas in the further manipulations of the pig iron.

At Zeltweg, near Leoben, the Oesterreichisch-Alpine Montangesellschaft have two blast furnaces each of eighty tons capacity, fifty-five feet high, seventeen foot bosh, which have been run for many years with a mixed fuel of Silesian coke and raw brown coal from the mines in the vicinity. The lines of the furnace now in use are given in Fig. 5, with measurements in meters.

The amount of brown coal used is governed by the comparative cost of coke and coal at the furnace. When coke or freight rates are high, or brown coal decreases in price, a greater per centage of brown coal is used, but as stated before, the brown coal is sold at such a high figure as to prevent its being used to the extent which it would otherwise be. At times there are equal amounts of brown coal and coke used, and according to Prof. Kupelweiser, it has been found practicable to use a mixture containing as much as seventy per cent of brown coal; but the average of these furnaces, as furnished me by the secretary of the company, gives for different periods something over thirty per cent of brown coal used.

These furnaces have been in practical operation for more than ten years, and afford most positive proof that raw brown coal of proper firmness can be used advantageously in the blast furnace, in connection with coke, for the production of pig iron.

COKING.

Experiments in the coking of brown coal have been made at many different times both in Europe and America.

Speaking in general terms, it has not been found practicable to make a coherent coke suitable for metallurgical purposes from brown coal under the ordinary conditions observed in coking bituminous coal. It is true that once in a while a variety of brown coal is found which affords

a fair coke (although it is usually in too small a quantity to be of value), and that some lignites yield a good charcoal.

"Even the best kinds of brown coal are not easily charred, as during the action of the heat the single layers, concentric rings, etc., which are scarcely perceptible in the fresh specimens, split off, and a compact piece of brown coal becomes thus completely broken up into small fragments or so fissured as not to bear carriage. Roschers states that lignite, if thoroughly air dried when fresh from the pit and very slowly charred, is not subject to this disintegration; and according to Mayer very fine charcoal is formed by charring the freshly dug lignite without previously exposing it to the air."*

The experiments which have been made may be classified thus:

The coking of the raw brown coal without addition of extraneous matter.

The coking of the raw brown coal together with the addition of caking coal, coal tar pitch, or other agglomerant, either directly or after compression.

The coking of brown coal previously charred, with addition of caking coal, coal tar pitch, or other cementing substance.

The earliest experiments in the direction of the coking of brown coal without addition of extraneous matter of which I have been able to find a record were the attempts to coke it in heaps or meilers, just as wood is charred. The results as stated were the production of a coke amounting from 15 per cent of the original material by weight in the Wetterau, and about 40 per cent in Cassel, which was of considerable hardness but in small sized pieces. This was succeeded by tests in brick ovens, but in nearly every case the result is the same—the production of a powdery coke, which was extinguished with difficulty when drawn.

Unger† says that a coke sufficiently good for blacksmithing was produced at the mines of Habichtswald from a woody pitch coal, and that the yield was about 44 per cent. He concludes that it is only from those brown coals which are rich in tarry matters, that there can be prepared by use of suitable methods compact coke giving an intensive heat which will closely approach that from bituminous coal.

The results of the experiments in Austria and Germany are briefly summarized in the pages just preceding, in connection with the preparation of brown coal for iron smelting.

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*Chemical Technology, Groves & Thorp, p. 119.

†Unger, Louis. Die Verwerthung der Braunkohle, etc., Weimar, 1863, p. 146.

The first American experiments of which I find publication are those of G. Christian Hoffman, Chemist and Mineralogist of the Geological Survey of Canada, 1884, and F. A. Gooch, in Vol. 15 of the Tenth Census Report, 1886.

The coal experimented with by Mr. Hoffman was a Cretaceous lignite (No. 2) of coarse lamellar structure, which he describes as follows:

"The various layers differ somewhat in lustre; contains an occasional interstratified layer of mineral charcoal; color black; lustre along the plane of bedding dull, that of the cross fracture sub-resinous and resinous; fracture uneven, that of some of the layers not unfrequently conchoidal; it communicates a deep brownish red color to a boiling solution of caustic potash; by exposure to the air splits along the plane of bedding and falls to pieces.

"Specific gravity, 1.3972.

"An ultimate analysis gave:

Carbon	54.35
Hydrogen	3.34
Oxygen and nitrogen	17.52
Sulphur	0.67
Ash	7.30
Hygroscopic water	16.82
	100.00

"It yields, both by slow and fast coking, a non-coherent coke; the gases evolved during coking burnt with a yellowish, somewhat luminous, slightly smoky flame. The ash has a reddish-brown color; exposed to a bright red heat it becomes slightly agglutinated; at a most intense red heat it forms a more or less vitrified mass.

"It appeared desirable in the case of those fuels which are only slightly non-caking, to ascertain what proportion of a caking coal would be required to be added to them in order to insure the production of a coherent, serviceable coke, and with this object in view the undermentioned experiments were carried out. No. 26 was selected to represent the lignitic coals and No. 2 the lignites. The caking coal employed was the well known Youghiogheny gas coal (Pennsylvania). The materials were reduced to the same state of mechanical division (tolerably fine powder); the weight of the mixture employed was in all instances the same, and the cokings were conducted as nearly as possible at the same temperature. The results are as follows:

Number of Experiment.	Proportions. Parts by Weight of		Character of the Coke.
	Number 26 (Lignitic Coal.)	Youghiogheny Coal.	
1	100	20	Firm, coherent; an excellent coke.
2	100	15	Firm, coherent; an excellent coke.
3	100	10	Firm, coherent; somewhat inferior to the one immediately preceding, but still of good quality.
4	100	5	Coherent, but tender; fairly good.

Number of Experiment.	Proportions. Parts by Weight of		Character of the Coke.
	Number 2 (Lignite.)	Youghiogheny Coal.	
5	100	20	Firm, coherent, good quality; about equal to that of experiment 3.
6	100	15	Coherent, somewhat tender; fairly good.
7	100	10	Coherent, but tender; inferior.

"From this it will be seen that, as far as experiments on the small scale are concerned, the addition of fifteen parts of a strongly caking coal to one hundred parts of the lignitic coal insures the production of a good strong coke; with ten parts of caking coal the product is still a good coke, and even the mixture containing only five parts of caking coal makes a coke which, although somewhat tender, might yet be found useful for some purposes. The lignite, it may be observed, requires a much larger addition of caking coal in order to insure equally satisfactory results; the mixture containing twenty parts of caking coal does not make a stronger coke than that obtained from the mixture of lignitic coal containing only half that amount of caking coal; with fifteen parts of caking coal, the coke was tender, though possibly still a useful fuel; that made from the mixture containing ten parts of caking coal can not be regarded as a useful coke.

"From the foregoing experiments it may, therefore, be inferred that, as regards the lignitic coal, the addition of fifteen parts of a strongly caking coal to one hundred parts of that fuel would be found to yield a good firm coke, and that about ten parts of caking coal is the smallest proportion that would be found to give satisfactory results; in the case of the lignite an addition of not less than twenty parts of caking coal to one hundred parts of lignite would be required in order to insure the production of a good coherent coke, and that fifteen parts of caking coal is the

smallest proportion that can be employed with any probability of obtaining a fairly good coke."*

The experiments as detailed by Mr. Gooch are with coals somewhat more nearly like our Texas brown coals, and for this reason I present the greater part of his report on them.

"The experiments, of which a brief account is here given, were, at the request of Mr. Pumpelly, the director of the Northern Transcontinental Survey, undertaken in the attempt to make from non-coking lignites of low grade and feeble heating capacity a good locomotive fuel of comparatively high calorific power, and, though the investigation was hardly more than begun when interrupted by the discovery and opening by the survey of the Bozeman coal field, it has been thought advisable to make record of such facts as were observed.

"Of all known modes of treatment something like the process of manufacture of the so-called Parisian coal or like that of the Welsh anthracite coke seemed best suited to the case of the lignites, and attention was accordingly turned in these directions. The mode of preparation of the Parisian coal consists, in brief, in the grinding of charcoal refuse with from 8 to 12 per cent of water, intermixing thoroughly 30 per cent of coal tar, molding the magma into cylinders, and coking the last in a muffle furnace. The product is said to be less fragile than ordinary charcoal and more inflammable than coke. The process of manufacture of the Welsh anthracite coke involves the intimate mixture of 60 parts of anthracite coal in fine powder with 35 parts of good caking coal and 5 parts of coal tar; and the coking of the mixture beneath a cover of two inches of bituminous coal. It is claimed for this coke that it is about 23 per cent heavier than the best Welsh coke from bituminous coal, gains only from 1½ to 2 per cent in weight when moistened with water, burns without decrepitating or crumbling, and is an excellent cupola or blast furnace fuel.

"The materials employed in these experiments were lignites from several localities on the line of the Northern Pacific Railroad in Western Dakota and Montana, bituminous coal from Connellsville, Pennsylvania, from Montana and from Washington Territory, the composition of which is given in the following analyses:

*"Experience has shown that, in the preparation of coke from a mixture of non-caking and caking coal, it is very desirable that the latter be reduced to a much finer state of division than the former. The two kinds of fuel should therefore be ground separately and afterward mixed in the desired proportions."

		Water.	Volatile Combustible.	Fixed Carbon.	Ash.
I.	Missoula	23.44	38.08	27.02	11.46
II.	Point 100 miles west of Miles City	21.56	38.12	28.29	12.03
III.	Montana (otherwise undescribed)	21.26	32.34	34.98	11.42
IV.	Little Missouri	25.53	35.18	33.59	5.70
V.	Bly mine	23.56	35.87	30.71	9.86
VI.	Wilkeson mine, Washington Territory	1.22	32.88	50.67	15.23
VII.	Montana	0.95	25.65	55.82	17.58
VIII.	Connellsville, Penn	1.53	30.13	60.17	8.17
IX.	III partly roasted	7.68	8.86	62.35	21.11
X.	IV partly roasted	9.98	12.50	60.32	17.20
XI.	V partly roasted	9.93	12.39	61.58	16.10

"The composition of the residue, after drying or after complete roasting of the lignites out of contact with the air, is, of course, readily seen in the figures of analyses I to V.

"In experiments 1 to 12, finely pulverized lignite from Missoula, the composition of which is given in analysis I, was employed with a coal tar which yielded 33 per cent of its weight of coke. Small amounts of material, from 5 to 10 grams, were used in each case, and the ignition was effected in closed platinum crucibles within the flame of a large gas blow-pipe, so that the coking might be accomplished at a high heat quickly applied, the most favorable condition for cementing the material and returning the largest yield of coke. In experiments 1 and 2 the lignite was taken in its natural condition; in experiments 3 and 4, after the expulsion of its water of composition, by drying at 115 degrees C.; and in experiments 5 to 12, after thorough roasting out of contact with the air to remove the volatile matter. The proportions used are given in percentages:

Locality.	Natural Lignite.	Coal Tar.	Treatment.	Residue.
1. Missoula....	76.9	23.1	.....	Not coherent.
2.....do	55.6	44.4	.....	Coherent, but granular and very fragile.
3.....do	65.0	35.0	.....	Coherent, but granular and very fragile.
4.....do	56.6	43.4	.....	Coherent, but granular and fragile.
5.....do	95.3	4.7	Mixture tamped	Feebly coherent
6.....do	91.6	8.4	Tar at bottom of crucible with lignite above it.	Feebly coherent
7.....do	91.6	8.4	Mixture not tamped...	Coherent, but granular and fragile.
8.....do	91.6	8.4	Mixture tamped.....	Coherent and hard, but not cellular.
9.....do	91.6	8.4	Moistened with naptha and tamped.	Feebly coherent.
10... .do	91.6	8.4	Moistened with water and tamped.	Feebly coherent.
11.....do	86.6	13.4	Moistened with water and tamped.	Feebly coherent.
12.....do	72.2	27.8	Not tamped.....	A true coke of fair color and structure.

"It is evident that under the conditions of these experiments a mixture of roasted lignite and coal tar is capable of producing a firm fuel, as in experiment 8, in which 19.3 per cent of tar was employed, or even a true coke of good structure, as in experiment 12, in which the roasted lignite was mixed with its own weight of tar. The bad effect of the presence of the volatile matter of the lignite is obvious in experiments 1 and 2, an amount of tar more than twice that of the fixed matter of the lignite proving insufficient to produce a firm cementing of the materials, and the removal of the water of composition alone seems to improve the matter a little. Tamping, or the compression of the mixture before heating, is advantageous, but, as would be expected from the results of experiments 1 to 4, the addition of volatile matter to the mixture is deleterious; and this effect appears to be due to the mechanical disintegration of the mass by the evolution of gas at the time when the fusion of the particles should be in process, rather than to chemical action, though it would not be unnatural to expect some dissociation of aqueous vapor at the expense of the carbon, more especially as the application of heat is sudden.

"In experiments 13 to 23 bituminous coals, either with or without the addition of coal tar, were used for the cementing material. In experiments 13 to 17 the roasted lignite of analysis II, the Washington Territory coal of analysis VI, and coal tar yielding 33 per cent of coke were employed, and in experiment 18 the same lignite was used with Montana coal of analysis VII. In experiments 15 to 18 portions of 400 grams were operated upon in fire clay crucibles in a Fletcher gas furnace, the crucible being at red heat when the mixture was introduced. In

other cases small portions of a few grams were treated in platinum crucibles as before. In experiments 19 to 23 the lignite from Montana, represented by analyses III and IX, in the natural, dried, partly roasted, and roasted conditions, was used in mixture with the Connellsville coal of analysis VIII.

	Natural Lignite.	Caking Coal.	Coal Tar.	Remarks.
13	90.8	9.2	.....	Firm and dense, but with no cellular structure.
14	78.8	21.2	.....	Firm and dense, but with no cellular structure.
15	86.4	8.7	4.9	Firm and dense, but with no cellular structure.
16	88.7	9.0	2.3	Firm and dense, but with no cellular structure.
17	88.1	9.5	2.4	Firm and dense, but with no cellular structure.
18	78.8	18.5	2.7	Firm and dense, but with no cellular structure.
19	50.0	50.0	.....	Firm, color excellent, structure porous with marks of fusion.
20	68.3	31.7	.....	Firm, color fair, structure porous, with marks of fusion on surface of contact with crucible.
21	68.3	31.7	.....	Firm, color good, structure porous, with marks of fusion on surface of contact with crucible.
22	68.3	31.7	.....	A true coke of good color and structure.
23	68.3	31.7	.....	A true coke of excellent color and structure.

"It appears from the first six experiments of the series just given that a firm fuel may be made under the conditions of the crucible experiments from mixtures containing proportions of caking material very much below those of the Welsh formula, though the Welsh proportions did not yield a true coke. Seventy-five per cent of roasted lignite, with 20 per cent of a caking coal (which though good is not to be placed in the same rank with the Connellsville coal) and 5 per cent of coal tar as serviceable proportions; so, also, is the mixture of 80 per cent of roasted lignite and 20 per cent of the caking coal.

"In the last five experiments the proportion of bituminous coal was equivalent to the fixed matter of the lignite, and the fuel produced was in every case firm, and in experiments 22 and 23 a true coke; but, as in the experiments in which coal tar was the sole cementing ingredient, the disadvantageous effect of the presence of volatile matter is clearly traceable, though in the case of the partly roasted lignites—material taken from that used in experiments on a larger scale, which are about to be described, and which was partly roasted simply because the complete roasting of the large sample was an impossibility with the facilities at command—the influence of the residual volatile matter was comparatively slight. Though, as was evident in the earlier experiments, the cementing quality of tar is adequate to the production of a true coke, these later experiments go to show very plainly that the value of good bituminous coal exceeds that of the same proportion of coal tar. Thus, while in experiment 2, 44.4 per cent of coal tar to 55.6 per cent of lignite in the natural

condition is a proportion capable of yielding only a fragile product, in experiment 19 equal parts of lignite and Connellsville coal produce a firm fuel of good structure and color, though not a true coke; and in the comparison of experiments 7, 8 and 13 the bituminous coal seems to have the advantage. It is to be noted, however, that the superiority of the caking coal over the tar is particularly obvious when the lignite still retains its volatile matter, and it may be that the advantage of the coal lies in the longer retention, during exposure to high heat, of the capacity to cake, so that a larger proportion of the gaseous matter of the lignite may escape and be out of the way of doing harm before the cementing of the material ceases.

"Experiments 24 to 36 were made upon a considerably larger scale, for the purpose of testing the conditions of the coking oven. The materials were taken from the large lots which had been prepared for the final experiments, 37 and 38. The roasting of the lignites was effected in retorts ordinarily used for making illuminating gas, and was but partial, because it was found necessary to stop the process before completion to prevent the wasting of fixed carbon by the action of the air, which, under the circumstances, could not be entirely excluded. Each charge was drawn as soon as it appeared to be ashing slightly on the surface, and drenched at once with water. A mill usually employed in grinding fire clay offered the only means available for pulverizing the roasted lignite and the bituminous coal, but the conditions imposed in the use of the mill, that the material should be worked in moist condition to keep the dust down, effectually prevented the grinding of the materials to that degree of fineness which was greatly to be desired. Much of the ground lignite and coal would scarcely pass a sieve of ten meshes to the linear inch. The mixtures were made in the proportions indicated in the tabular statement, and small portions of each mixture were tested in the crucible after the manner of the experiments previously described. The portions experimented upon, varying from 150 to 400 pounds in weight, according as sacks or barrels were used to contain them, were thrown directly upon the hot bottoms of bee-hive ovens, from which the charges had just been drawn, immediately covered with the new charge of caking coal, and quenched and drawn with the charge of the oven after forty-eight hours. The analyses of the products are included in the table.

Materials.	24.	25.		26.
	Montana lignite; Connellsville coal; coal tar.	Montana lignite; Connellsville coal; coal tar.		Little Missouri lignite; Con'llsv. coal; coal tar.
Natural lignite	84.4	84.4		85.5
Caking coal	11.8	11.8		10.9
Coal tar	3.8	3.8		3.6
Weight of charge—pounds	320	150		150
Residue	Firm fuel	Fairly firm fuel		Rather fragile.
		Upper.	Under.	
Water	5.98	5.71	4.70	7.21
Vol. matter	4.33	5.39	3.97	8.51
Carbon	70.24	69.08	69.50	68.25
Ash	19.45	19.82	21.93	16.03
	100.00	100.00	100.00	100.00

Residue in parallel crucible experiments.....Color excellent, but grain coarse.

Materials.	27.		28.	
	Little Missouri lignite; Connellsville coal; coal tar.		Bly Mine lignite; Connellsville coal; coal tar.	
Natural lignite	85.5		85.3	
Caking coal	10.9		11.1	
Coal tar	3.6		3.6	
Weight of charge—pounds	150		150	
Residue	Weak fuel		Weak fuel.	
	Upper.	Under.	Upper.	Under.
Water	6.54	6.02	4.84	5.23
Vol. matter	5.79	7.06	8.07	7.30
Carbon	70.05	72.11	66.24	65.72
Ash	17.62	14.81	20.85	21.75
	100.00	100.00	100.00	100.00

Residue in parallel crucible experiments.....Color excellent, but grain coarse.

Materials.	29.	30.
	Montana lignite; Connellsville coal.	Montana lignite; Connellsville coke.
Natural lignite	87.8	84.4
Caking coal	22.2	15.6
Weight of charge—pounds	400	300
Residue	Too fragile to be drawn	Feebly coherent.
Water	.....	6.53
Vol. matter	.....	5.10
Carbon	.....	68.89
Ash	.....	19.48

Residue in parallel crucible experiments.....Color excellent, but grain coarse.

Materials.	31. Montana lignite; Connellsville coal.	32. Montana lignite; Connellsville coal.
Natural lignite	78.5	73
Caking coal	21.5	27
Weight of charge—pounds	300	300
Residue	Firm, but not a true coke.	A fair coke, of good color and structure.
Water	6.59	2.79
Vol. matter	6.73	3.09
Carbon	67.71	75.07
Ash	18.97	19.05
	100.00	100.00

Residue in parallel crucible experiments.....Color excellent, but grain coarse.

Materials.	33. Montana lignite; Connellsville coal.		34. Montana lignite; Connellsville coal.
Natural lignite	73		64.3
Caking coal	27		35.7
Weight of charge, lbs.	150		220
Residue	Good coke, of good color and structure.		Good coke, of good color and structure.
	Upper.	Under.	
Water	3.50	5.63	2.79
Vol. matter	4.29	6.93	3.09
Carbon	70.71	68.34	75.07
Ash	21.50	19.10	19.05
	100.00	100.00	100.00

Residue in parallel crucible experiments.....Color excellent, but grain coarse.

Materials.	35. Little Missouri lignites; Connellsville coal.		36. Bly Mine lignite; Connnellsville coal.	
Natural lignite	74.8		74.2	
Caking coal	25.2		25.8	
Weight of charge, lbs.	150		150	
Residue	Weak fuel		Fairly firm, of good color, but not a true coke.	
	Upper.	Under.	Upper.	Under.
Water	5.75	5.63	4.97	3.13
Vol. matter	7.60	4.49	8.77	4.37
Carbon	71.93	75.05	70.25	74.87
Ash	14.72	16.52	16.01	17.63
	100.00	100.00	100.00	100.00

Residue in parallel crucible experiments.....Color excellent, but grain coarse.

"Experiments 24 to 28 indicate pretty clearly the lowest proportions of cementing material, by the admixture of which with the roasted lignites, it may be hoped to secure a good fuel by coking. Why experiments 26, 27 and 28 should have yielded a feebly coherent product under apparently the same conditions of mixture and experimentation, which in experiments 24 and 25 gave a firm fuel, is difficult to see, unless the cause is to be sought in the larger amount of volatile matter still remaining in the partly roasted lignite of the first experiments. At any rate, it is evident that these proportions lie near the limit of successful cementing. Experiments 29 to 36, with the companion tests, show unmistakably that the conditions of the crucible experiments are more favorable to the production of firm cokes of good color than the conditions which prevail beneath the surface of coal in process of coking in the bee-hive oven, and a comparison with experiments 13 to 18 and 23 emphasizes the value of a fine comminution of materials.

"In experiments 37 and 38 the materials were mixed for oven charges, as indicated in the table following, and thrown into hot bee-hive ovens. Heating began immediately, and a coherent crust formed upon each charge and the surface cracked in an encouraging manner. In the case of experiment 37, however, it was possible to run a pole to the bottom of the oven after eight hours heating, and upon drawing the charge at the end of twenty-four hours the product was worthless, excepting the thin surface crust. In experiment 38 the product, drawn twenty-two hours after charging, proved to be a good coherent fuel, but not a true coke. This fuel was used with success on a 27-ton locomotive, and gave every indication of being applicable to locomotive use, and the material was preserved for quantitative tests.

Materials.	37.		
	Montana lignite; Connellsville coal; coal tar.	Little Missouri; Connellsville coal; coal tar.	Bly Mine lignite; Connellsville coal; coal tar.
Natural lignite	84.4	85.5	85.3
Caking coal	11.8	10.9	11.1
Coal tar	3.8	3.6	3.6
Weight of charge—pounds	2000	2000	2000
Residue	Thin crust on surface.		
Water	.....	.....	.....
Vol. matter	.....	.....	.....
Carbon	.....	.....	.....
Ash	.....	.....	.....

Residue in parallel crucible experiments.....Color excellent, but grain coarse.

Materials.	88.		
	Montana lignite; Connellsville coal.	Little Missouri lignite: Connellsville coal.	Bly Mine lignite; Connellsville coal.
Natural lignite	73	74.8	74.2
Caking coal	27	25.2	25.8
Weight of charge—pounds	1330	2730	1330
Residue	Fairly firm, but not a true coke.		
Water	6.92		
Vol. mattr	7.54		
Carbon	69.24		
Ash	16.30		
	100.00		
Residue in crucible experiments	Color excellent, but grain coarse.		

"From the experiments which have been cited, it is plain that not only a good fuel, but a fuel possessing the qualities of a true coke, may be made under the conditions of the crucible experiments from mixtures of roasted lignite with either a coking coal or coal tar, and the conclusion that the more thoroughly and quickly the heating of the mass takes place, the better will be the product, seems warranted. Fine pulverization of the materials before coking is shown distinctly to be advantageous in experiments on the small scale, which suggests at least the trial of the same mode of preparation on the large scale. The bee-hive oven is manifestly unsuited to the coking of material not abundantly charged with bituminous constituents, but some one of the many devices which have been lately put forward as improvements upon the plan of the Belgian ovens would doubtless prove valuable in such cases, some arrangement by which the material may be compressed and coked in thin layers being apparently most promising. Perhaps the most important point which has been brought out by these experiments in reference to the treatment of lignites by coking in mixture with bituminous materials, is the great advantage to be gained in the removal of the volatile constituents before making the mixture to be coked. In the crucible experiments the yield is the sum of the fixed matter of the coal, the lignite and the tar, as given by the ordinary proximate analysis; on the working scale, it is probable that the waste of fixed carbon need not exceed that which is usual in the coking of bituminous coal. While the experiments have not been carried far enough to warrant a close estimate of the cost of producing the proposed fuel, the results justify the belief that this would not be prohibitory where the alternative was the bringing in of Eastern coal."

CHAPTER V.

BROWN COAL AS FUEL — continued.

ARTIFICIAL FUEL.

The name briquette,* which is now used for every variety of artificially formed combustible, was originally used in Paris for fuel formed from peat with addition of water and plastic clay; later it was applied to fuel formed by pressure at a high temperature from good agglomerating coal, but without addition of a bond, to distinguish them from those termed "pérats," under which name were included the fuel first made by Bérard and Givors from bituminous coal with tar, pitch or other bond. Numerous other names, such as "charbons agglomérés," "houilles agglomérés," or for short, "agglomérés," in France, "briquettes de charbon" in Belgium, "patent fuel" or "compressed fuel" in England and North America, "kohlensteine" or "kohlenziegeln" in Germany, were all used in a restricted sense for pressed fuel from bituminous coal only, while under "combustibles artificials" and "artificial fuel" were embraced every sort of artificially prepared fuel. In Germany, pressed brown coal was designated by such generally used terms as nass-press-steine (also presskohlensteine) and darrsteine (or darrkohlensteine), in accordance with the two different methods of preparation.

Numberless experiments for the preparation of coal for use by pressing were conducted in different directions and by different methods, but the difficulties to be overcome were very considerable, both from a chemical and a mechanical point of view, and it required a very long time after the principle was understood before it was found possible to enter upon the manufacture successfully, and for this reason the real production of briquettes from bituminous coal may be said to date only from 1860, and of brown coal from 1870. Since that time the improvement has gone on steadily, and there is hardly any doubt that materials now regarded as unbriquettable in this manner may finally, under sufficient pressure, be

* Preissig, E. Die Presskohlen-Industrie, Freiberg, in Sachsen, 1887.

formed into a fine briquette without a bond. But the question of cost, of method and machinery requisite, and whether the material is briquettable in this way with profit, must be fully considered before any great expense is incurred.

After the first establishment of a manufactory for this character of fuel at St. Etienne, France, in 1842, it spread into England, Belgium, and elsewhere, and when the price of the bond was materially lessened, by the saving of the tar from the coke ovens, it gathered fresh headway, until at the present time factories are in operation in France, Belgium, Holland, England, Spain, Italy, Russia, Sweden, Germany, Austria, Hungary and the United States.

The present conditions of briquette technology are such that outside of peat, certain kinds of brown coal, and possibly caking coals, briquettes can not be manufactured without a bond of some kind, while by the use of such a bond all possible fuels may be converted into pressed coal, and thus made serviceable.

QUALITIES OF BRIQUETTES.

Schwackhöfer gives the following as the qualities of good briquettes:

a. They must be homogeneous, ringing, and nearly smokeless.

b. The breakage in transportation must not exceed 5 per cent.

c. The weight of each briquette should not exceed one to two and one-half pounds, so that they can be used handily and without breaking in feeding the furnace.

d. The average specific gravity should be at least 1.15.

e. They must not be hygroscopic. The moisture contained in them should not exceed 5 per cent, and the ash should not be more than 10 per cent.

f. They must be easy to kindle, burn with a lively and practically smokeless flame, and must not fall to pieces in the fire.

g. Their steaming power must be approximately equal to that of a good steam coal.

For certain purposes, however, such as use in locomotives or in ships' furnaces, larger sizes are made, reaching in the French marine to briquettes weighing twenty-two pounds each, and even a greater size. The limits of water and ash are also changed under certain conditions, but the water and ash together should never exceed the maximum here given.

Briquettes complying with these requirements are sold in Westphalia at about the same price as the best bituminous coal, in England at the same relative price and even higher, while in Russia they are preferred to bituminous coal and bring a higher price.

Form, Size and Weight.—The forms of briquettes of this character in most general use are prismatic or cylindrical, more rarely egg-shaped, or perforated prismatic forms.

Such briquettes are of a great variety of sizes and consequently differ as widely in weight.

Heating Power.—One especial advantage of good coal briquettes over the coal itself, and one which remains unaltered for a very long time, is their higher heating power. This has been amply proven by many experiments in England, France, Germany and Austria. The heating power is of course largely governed by the character of the coal of which they are made, and this increase can not be entirely attributed to the pitch which is added as a bond, since the amount ordinarily added would not raise it more than 2 per cent. The higher heating power is therefore partly due to the more complete combustion of the briquettes or to the cleansing of the coal previous to briquetting it.

Behavior in the Fire.—For the best service the briquette should not have the quality of caking or running together in the fire, and thus preventing a free passage of air; neither should it fall apart, but it should hold its form and burn steadily from the outside inward. The character of bond used has considerable influence over the behavior, and, according to Gurlt, briquettes formed with magnesia cement give excellent results, neither running together nor falling apart, but those cemented with pitch are so far considered the best, since even at a high temperature the gases are evolved gradually and their dissemination in the mass produces a lively and intense flame.

Firmness and Durability.—These are also influenced to a large degree by the kind of bond and the degree of pressure used in the manufacture. When proper pressure is given the bulk of the fuel is reduced and its durability greatly increased. Thus in the French marine it has been found possible to store in the same space 10 per cent more briquettes than coal, and that the loss by breaking and pulverization is very much less.

MECHANICAL PREPARATION OF THE COAL.

The size of the particles of coal and its cleanness or freedom from extraneous matter are weighty factors in the manufacture of briquettes. If the coal be well mixed with the bond and subjected to strong pressure, the particles may have a diameter of five, or at the highest seven, millimeters (three to five-sixteenths of an inch). The most satisfactory product is from coal of an even size of one-eighth of an inch (three millimeters) or from the slime of slack.

"The cleaner the product the higher the value, and so much the more widespread will be its market." This principle, founded on experience, holds as well for briquettes as for coal and coke, of which the quality is judged, aside from its heating power and other characteristics, especially according to its cleanliness. It is therefore best to separate all slate, pyrites and other foreign materials as completely as possible by separation and sorting, and to complete this by washing the coal after it has been reduced to proper size. By this means the briquettes often contain much less ash than the coal from which they were made.

The mechanical preparation of coal for briquetting consists of three operations:

Separation;

Crushing;

Cleaning.

These operations are so fully described in all the standard works on the subject that it is hardly necessary to do more than refer to them here.

SEPARATION.—The coal as it comes from the mine is sorted by hand, or separated into different sizes by a system of sieves or other suitable apparatus, the lump coal passing to the crusher, and the fine coal to the washing apparatus.

CRUSHING.—The apparatus for crushing is either a breaker or a crusher of the ordinary type, or a disintegrator of special construction. The latter seems to be preferred in Belgium, France, Germany, and Austria, as it produces a fine coal of very uniform size and homogeneity.

CLEANING.—In order to secure the smallest possible amount of ash and sulphur in the briquettes, the fine coal is washed to rid it of its clay, sand and iron pyrites, just as in preparing it for coking. The great im-

provement caused by washing is most clearly shown by the following table:

	Ash.	
	Raw coal.	Washed coal.
Wolfsbank mine, Westphalia	8 per cent.	2.79 per cent.
Hörder mine, Westphalia	22 per cent.	3.5–5.77 per cent.
Forst pit, Saxony	22–24 per cent.	5.8–6 per cent.
Brückenberg, Saxony	25 per cent.	5–6 per cent.
Meyram pit, near Gottesberg, Silesia	17–18 per cent.	4.5–6.35 per cent.

The cost of such washing, including interest, superintendence, etc., was from five to six cents per ton of washed coal at Wolfsbank and Brückenberg.

There are a variety of forms of apparatus in use for washing the coal, and each has its special claim for excellence, or its application to a particular character of work, one of the largest plants of this kind being that of the briquette factory of Couillet, in Belgium, which has a capacity of 1000 tons in ten hours.

The drying of the washed coal is usually done by means of centrifugal machines, which make 300 revolutions per minute, and have a capacity of three tons per hour. At other localities the drying is carried on in drying towers.

The separation and cleaning of coal in the dry way is also in successful operation at several localities, and while the cost of installation of the plant is somewhat greater than in the washing apparatus, the cost of cleaning is about 20 per cent less. There seems to be some advantage in it, since the coal is worked with dry air and the cost of drying after washing is saved entirely.

BRIQUETTES WITH BOND.

The greater quantity of briquettes which are made with bond are manufactured from the slack of coal with the addition of coal tar pitch. The earthy brown coal of Germany is not well adapted for the manufacture of briquettes of this kind, and while the pitch coal and glance coal of Austria are well suited for the purpose, the demand for the coal, small as well as large, is so great that up to the present time there have been few plants erected. Where they have been, however, they are in suc-

cessful operation. In Italy, where the brown coal is almost the only source of supply, this method of converting it into a serviceable fuel is receiving considerable attention, and in many of the factories the brown coal forms a part at least of the material briquetted.

THE BOND.

In the beginning of the briquette industry many kinds of material, both inorganic and organic, were used as bonds, but at present the organic are used almost exclusively.

Among the inorganic substances used at different times may be mentioned the clays (some of which are still in use today in preparation of certain coals for household purposes when the increase of ash is not such an important matter), silicate of soda, alum, alum shales with quick lime, lime water, etc. Many other materials were added to the inorganic bonds for the purpose of increasing the inflammability of the briquettes or to decrease the production of smoke and soot. Some of these were saltpetre, chlorate of potash, magnesia, slacked lime, potash, soda, nitric acid, hydrochloric acid, permanganate of potash, etc. None of these, however, are now in practical use, and the only substitute for pitch which is at present worthy of attention is magnesia cement.

ORGANIC BONDS.

Coal Tar.—This material was used as bond in the oldest briquette factories, but the product was not firm enough to bear long transportation, or to withstand the heat of the sun. It develops also in burning a dense black smoke and a very disagreeable odor, and although many trials were made to overcome these disadvantages by thoroughly drying the briquettes in dry kilns, the results were unsuccessful. For these reasons, coal tar is now scarcely used in its raw state, but is sometimes added to the material for the purpose of increasing its combustibility. Its real value lies in the fact that it is the material from which the pitch used can be distilled. For this purpose only the tar from bituminous coal is generally made use of, because that from brown coal, peat and bituminous shales is found more valuable in Europe as the basis of the manufacture of mineral oil and paraffine. Pitch from wood tar and petroleum might also be used, but so far has not been applied in this direction.

Coal tar is a product of the distillation of coal, by which it is separated

into tar, ammonia and gas as distillates, and coke which is left as residue. The tar consists principally of hydrocarbons, but includes also other neutral bodies, as well as some that are acid and basic, the character of which is not constant, but depends upon the composition of the coal, method of distillation (especially the temperature), influence of the heat, and form and size of the vessel used. The quantity of tar produced from different coals varies directly in proportion to the hydrogen they contain, and the regularity of the temperature and the degree of heat used. High temperatures produce carbon and carbonic gases of little light-giving power, with slight amounts of liquid distillates, while lower temperatures afford large amount of fluids and gas of higher light-giving power.

Under the present modes of manufacture, tar is only a by-product, and not the principal object of production. The sources from which it is derived, are the manufacture of gas and coke, and, in far less quantities, from the gases of iron furnaces using raw coal as fuel. The residue from the distillation of petroleum is not included in this.

England is by far the greatest producer of coal tar, having an output of about half a million tons annually, nearly twice as much as is made in all the other parts of Europe.

The earlier tar output was confined exclusively to the gas works, but the application of methods for saving both tar and ammonia from the gases driven off in the coking of coal in ovens has increased the output very greatly. As these ovens vary in construction and in the degree of heat used, the tar is also variable, being in some cases similar to gas tar, and in others much thinner and lighter. The heat employed in distillation ranges from 800 degrees C. in retorts to 1600 C. in recuperative ovens. The product from the coke ovens also varies from 2.11 per cent to 3.5 per cent of the weight of the coked coal. The ammonia recovered at the same time in the form of ammonium sulphate averages about 1 per cent, and these by-products have a value of from fifty cents to one dollar and fifty cents for each ton of coal.

From the iron furnaces using raw coal as fuel the tar is collected by condensation of the escaping gases.

Pitch.—Pitch is the residue of tar after the distillation of substances volatile under a certain temperature. The distillation is carried on in upright cylinders of boiler iron by direct heating. Below 140 degrees C. the light oils (benzene, toluene and homologous oils) are driven off;

between that point and 220 degrees C. light and heavy oils together, (the higher homologues of benzene, napthalene and carbolic acid); between 300 degrees C. and 400 degrees C. anthracene (with phenanthrene and higher homologues of the phenol group). The residue still fluid at 400 degrees C. will, when cooled in the pitch chamber, form hard pitch. If the distillation be stopped at the completion of the separation of the light oils, the residue is asphaltum, with a specific gravity about equal to water. Soft pitch is the residue when about half of the heavy oils have been driven off and the distillate has reached a specific gravity of 1.09. The specific gravity of medium pitch is between 1.09 and 1.12, while hard pitch sometimes reaches 1.28.

Soft pitch.....Softens at 40 deg. C.	Melts at 60 deg. C.
Medium pitch.Softens at 60 deg. C.	Melts at 100 deg. C.
Hard pitch....Softens at 100 deg. C.	Melts at 150 deg. C. to 200 deg. C.

The yield of pitch from tar may be stated to vary between 50 and 67 per cent of hard pitch, or from 60 to 75 per cent of soft pitch.

In the manufacture of briquettes hard pitch is generally preferred, though both soft and medium pitch are used to some extent. The liability of the latter to soften at low temperatures, however, would prevent its being serviceable in warm countries.

The amount of pitch used in briquetting varies from 4 to 10 per cent of the weight of the coal used.

In America there has been little incentive to the recovery of the pitch and ammonia produced in the coking of coal, since the chemical works, which in Europe are dependent on this source of supply for their materials, have here the same materials in the residuum of the distillation of coal oil in great abundance and at extremely low prices. Of late several articles have appeared in the proceedings of the different scientific associations urging the erection of coking ovens properly arranged for this purpose. An extension of the process of briquetting to the smalls of anthracite and bituminous coal would create so great a demand for this material as to render such plants quite remunerative.

Starch Paste and Dextrine.—Starch, although insoluble in cold water, forms a paste of a more or less gelatinous character in water having a temperature between 40 degrees and 70 degrees C. Heated carefully from 160 degrees to 200 degrees, or with addition of an acid from 100 degrees to 120 degrees, the starch is changed into dextrine,

which is soluble in both hot and cold water. Rye meal, potato meal, and flour have been used in the production of briquettes, and in Dixon's patent fuel, which is so extensively used in England, dextrine is the cementing substance, supplemented by hard pitch, fusel oil and alum. These briquettes have given most excellent results both in smelting tests and for household purposes.

Irish Moss.—This material, which was used formerly and had the merit of being very cheap, was hygroscopic and therefore has been laid aside.

Paper Pulp or Cellulose.—Patents were taken out for the use of this material for bond, but after tests on a large scale it was found that briquettes made with it would not withstand moisture, and after experiments failed to remedy the defect it was abandoned.

Molasses.—This material was brought into use as bond for briquettes by Bérard, but in 1884 its use was greatly extended by Saltery's patent for briquetting ores, coal, coke, sawdust, etc. Coal briquettes made with it have all the characters of those agglomerated with hard pitch except their imperviousness to moisture. If this property can be attained by the addition of a small amount of linseed oil, as has been suggested, the cheapness of the bond will be greatly in favor of its use. The quantity required for successful agglomeration depends upon the percentage of sugar and gummy substances in the molasses, and in some measure also on the caking or non-caking character of the coal. It is usually between 1 and 1½ per cent of the coal. There seems to be some improvement needed in the technique or machinery of the operation for mixing the molasses through the coal, and it is also necessary to dry the briquettes artificially before they can be stored or shipped.

INORGANIC BONDS.

Magnesia Cement.—This is a patent cement composed of magnesia and chloride of magnesia with 50 to 60 per cent of water of hydration. It is produced from the refuse of the potash works at Stassfurt. It forms a very plastic paste with water, which hardens under change of temperature.

The cementing power of this material is so great that it will bind together twenty times its own weight of other substances, such as sand, etc., into blocks so hard that they will withstand a pressure of 500 to

1500 kilogrammes to the square centimetre. Small coal mixed with only 5 per cent of the magnesia cement (of which 2½ per cent remains as ash) will produce hard, firm briquettes. They require a pressure of 150 to 250 kilogrammes per square centimetre, and the briquettes require twenty-four hours to become completely dry and hard, and should not be exposed to rain for at least three days. The amount of ash, and the fact that it does not increase the calorific power of the material, would not recommend it for use with brown coal except under very special conditions, despite the advantages offered in cheapness of plant required for using it.

As stated previously, however, pitch is the bond most extensively used, either by itself or sometimes with the addition of a small percentage of coal tar. Hard pitch is the variety in most general use, although machines of the Evrard system, which use only soft pitch, are also in use in considerable numbers.

In Russia the use of bitumen is reported, but whether the material is of natural occurrence or the name is simply used for a manufactured article, does not appear.

MIXING COAL AND BOND.

In the manufacture of briquettes it is of the highest importance that there should be the most intimate mixture possible of the coal and its bond, and to accomplish this there are as many processes as there are bonds, if not more. Certain bonds, such as Irish moss, dextrine, silicate of soda, clay, magnesia, cement, etc., can be mixed with the coal without the aid of heat. By Saltery's patent the molasses is dissolved in warm water and then mixed with the coal in a mixing cylinder, which resembles a clay-cutting machine. While the processes require a less costly plant than those employing heat, the briquettes produced must be dried after manufacture, either in the air or by artificial heat, before being ready for market.

The methods which give the best results are those which heat the coal and bond and press them while in that condition.

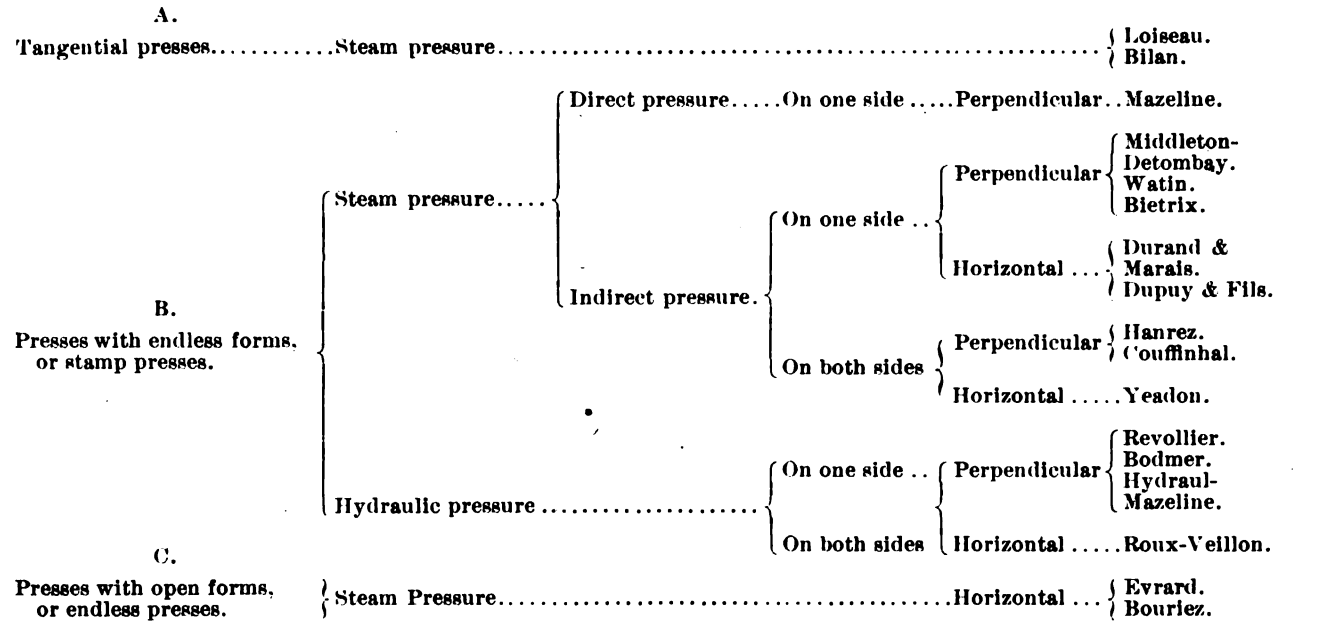
Hard pitch may be powdered and mixed with the fine coal, and the mixture passed through pulverizers of suitable construction to reduce both to the requisite fineness, and the mixture then heated to secure the plasticity necessary for perfect agglomeration, or the pulverized and

heated coal may be mixed with the pitch in a liquid condition; or the coal only may be heated and then mixed with the powdered pitch in a suitable apparatus, and the whole brought to a plastic state, preferably by means of superheated steam.

These methods with their various modifications are in use at different localities, and the one best adapted for any given coal is determined by its character, the machinery to be used and the fuel to be produced.

BRIQUETTE PRESSES.

Preissig gives in the following table the different varieties of presses used in briquetting fine coal with bond:


A.
Tangential presses
Steam pressure
Loiseau.
Bilan.
B.
Presses with endless forms, or stamp presses.
Steam pressure
Direct pressure
On one side
Perpendicular
Mazeline.
Indirect pressure.
On one side
Perpendicular
Middleton-Detombay.
Watin.
Bietrix.
Horizontal
Durand & Marais.
Dupuy & Fils.
On both sides
Perpendicular
Hanrez.
Couffinhal.
Horizontal
Yeadon.
Hydraulic pressure
On one side
Perpendicular
Revollier.
Bodmer.
Hydraul-Mazeline.
On both sides
Horizontal
Roux-Veillon.
C.
Presses with open forms, or endless presses.
Steam Pressure
Horizontal
Evrard.
Bourlez.

A. Tangential Presses.

The earlier presses of this character have been replaced by those with stamps, and those designed by Loisseau, in America, and Bilan and Fouquemberg, in Europe, are the only ones in practical use, and their use is at present comparatively limited.

Bilan's machine is thus described in "Annales Industrielles:"

"This machine is designed for manufacturing agglomerated fuel in spherical shape for domestic purposes. It consists of a frame of cast iron, which is the support for four vertical moulding wheels placed at right angles to each other, and tangent to the line of centers. These wheels have their periphery cut into cavities that have the form of one quarter of a sphere; thus they form at the point of contact a complete sphere, in which the material is enclosed.

"The fine coal is mixed with 8 to 10 per cent of coal tar pitch, thrown into a crusher and pulverized and intimately mixed. It then passes into a pug mill and is there converted into a plastic state by means of superheated steam. The paste is then conducted into an agitator for the double purpose of freeing it from the steam that it contains, and of distributing it in the moulds of the briquette machine. From a hopper at the upper part of the frame the paste is taken up on two endless screws and forced toward the point where the four moulding wheels meet.

"The driving pulley of the machine is keyed upon a horizontal shaft, which, by means of two endless screws, communicate the motion to two gear-wheels, and then by means of beveled pinions set the four moulding wheels in motion.

"The four moulding wheels are so accurately adjusted that their cavities meet each other at each revolution, carry along the paste which they receive from the hopper, compress it powerfully on the four sides, and as they separate by farther revolution permit the finished ball to fall out.

"The rim of the four wheels which carries the quarter spheres is made in four segments and fastened by bolts, so that they can be taken apart and replaced with new ones when necessary.

"The capacity of the machine is about forty tons per day."

The alterations made on this press by Schüchtermann and Kremer, Dortmund, are said by Preissig to increase its efficiency.

Loisseau's Press.—This press, being one of the very few erected in America, deserves somewhat more extended notice than I am able to give it. In principle it is the same as the Bilan, but instead of four wheels, the cavities of which form a sphere, he uses

"Two rollers, each thirty inches in diameter, and thirty-six inches

in length, containing on the surfaces semi-oval cavities, connected together by small channels, which allow the escape of air and excess of material; each cavity or recess communicates by four of these channels with the surrounding ones. These cavities extend in close proximity to each other, in regular rows, over the whole length of the rollers, the recesses of every other row being intermediately between those of the adjoining row, in the nature of the cells of a honey-comb, so that small metallic contact surfaces are formed, and the entire surfaec of the rollers is utilized for compressing the composition into lumps of an egg-shaped form. The shafts of the rollers are cast solid with the rollers, and they are ten and one-half inches in diameter. Each roller weighs over a ton. On top of these is a hopper thirty-six inches long and thirty inches wide, in which the materials to be compressed are discharged from the mixer. In this hopper a series of knives, screwed to a small horizontal shaft, revolve rapidly, and keep the material in a granulated state."

This description, taken from his paper in the Transactions American Institute of Mining Engineers, Vol. VI, 1877-78, p. 216, is the only one to which I have had access, although several machines made on this pattern are now in use in the United States for briquetting coal slack.

Presses with Endless Forms, or Stamping Presses.

The general principle of this character of presses is a rotating table, pierced with moulds of the size and shape desired in the briquette, the pressure being given by means of a plunger, operated by steam or water power. The pressure may be applied either by direct action of the power from the piston rod, or, as is most usual, indirectly by means of levers, etc.

STEAM PRESSES.

The principal press, which was formerly operated under the first of these methods — steam applied directly — is the Mazeline, the general operation of which will be given fully in its improved form under Hydraulic Presses.

Of the steam presses in which the power is applied indirectly, we have first the English press of Middleton, afterwards improved by Détombay, of which a great number have come into use in different parts of Europe.

The Watin press, and also that of Biétrix (model of 1878), are of the same general type as the Middleton-Détombay, but differ from it in

ARTIFICIAL FUEL

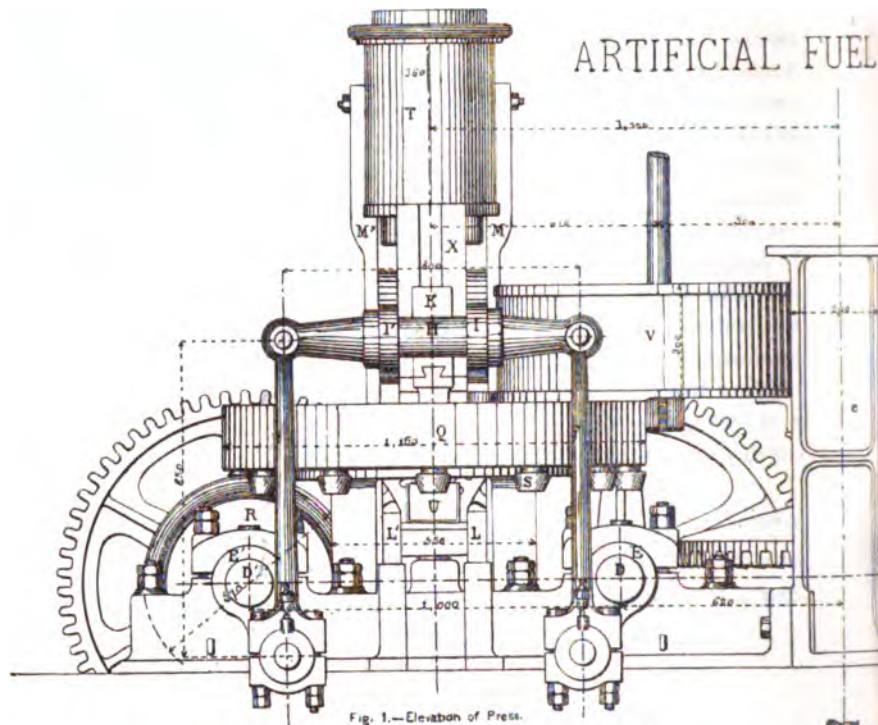


Fig. 1.—Elevation of Press.

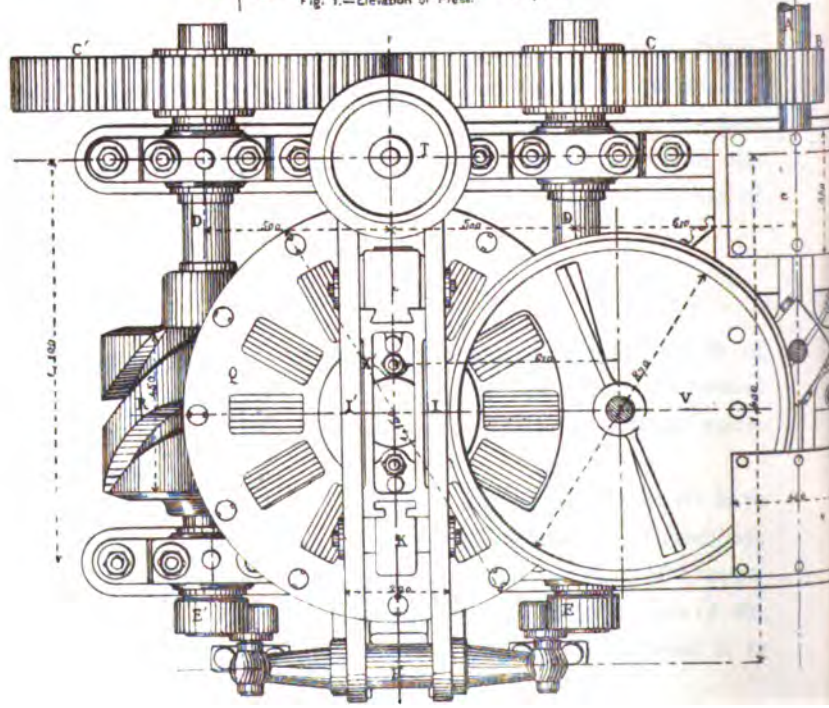


Fig. 2.—Top View.

CHINERY

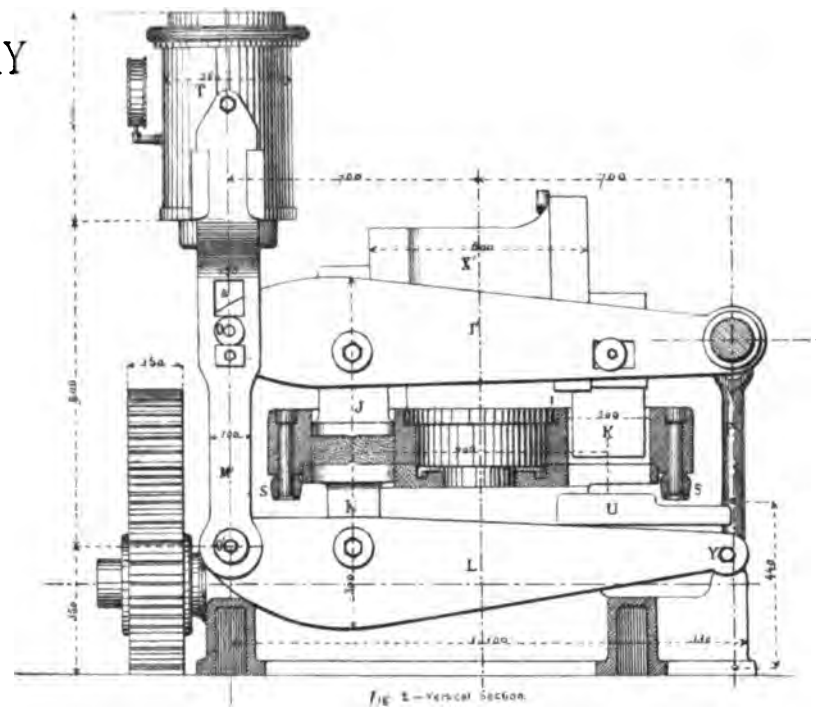


Fig. 2.—Vertical Section.

Fig. 3.—Section along m n, of Fig. 4.

Fig. 5.—Shape of Molds.

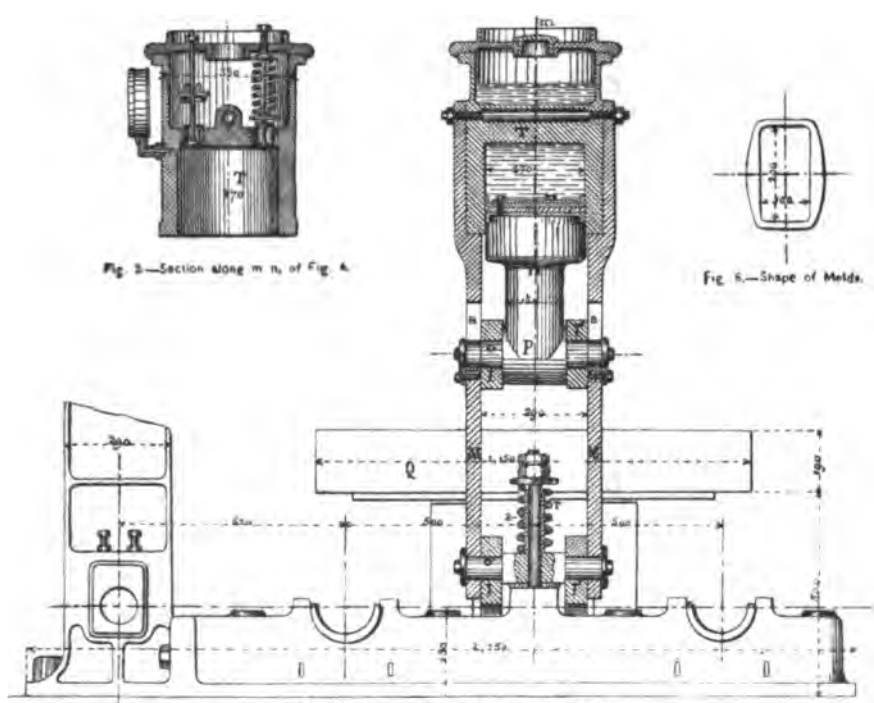


Fig. 4.—Vertical Section of Hydraulic Regulator.

mechanical movement. In presses of this type the pressure is applied vertically, but in those manufactured by Durand and Marais, and Dupuy and Fils, at Paris, the pressure is applied horizontally. It would appear from the number of the various machines in use that the former system is preferred.

All the above mentioned presses were of the single compression type, but have now been improved by the use of double compression. The first of these improved presses was the Hanrez, manufactured and used in Belgium, which is a combination of the Middleton press with certain features of the Mazaline, and has given great satisfaction.

This was followed by an improvement in the Biétrix by Couffinhal, and the result is the press bearing his name, which gained gold medals, both for the machine and the inventor, at the Paris Exposition of 1889. Its character and construction are plainly shown in the illustrations in Plate XIV. The following description gives not only the details of construction, but is sufficient to explain the general principles on which all presses of its class are constructed.

Couffinhal Press.—The machine is set in motion by a horizontal shaft, A (Fig. 3), which may either be operated directly by the engine or by a counter shaft.

The principal shaft transmits its motion by means of a pinion, B, to two geared wheels, C C, chocked on two shafts, D D, symmetrically situated with respect to the principal axis of the press. These are furnished on their opposite extremities with cranks, E E, which work the two vertical rods, F F (Fig. 1). These rods are attached to a horizontal yoke, H, which transmits its motion alternately in rising and falling to two levers, I I, situated above the moulding table. These levers carry the two pistons, J K (Fig. 2), one of which compresses the fuel, the other expelling it from the moulds.

These latter are guided by a central piece, X, fixed to the frame. A second pair of levers, L L, similar to the preceding but below the moulding table, carry the piston of the lower compressor, N. They turn around on an axle situated in front, and their further extremities are connected with the corresponding extremities of the first pair by the two shafts, O O (Fig. 2), which carry the hydraulic regulator.

Since the compression is produced by the stroke of the levers and compressor piston, which are above the table, there comes a moment

when the upper part of the briquette does not fall in consequence of the resistance offered by the lower piston and of friction met with by the coal against the walls of the mould. At this instant, the lower face having less pressure than the upper, a reaction is produced, the latter surface becomes a fixed point and the lower piston moves in its turn so that pressure is made equal on both sides. The mechanism is very similar to that of a pair of nut crackers; it could not be more simple.

In this machine, as in that of the model of 1878, it is possible to regulate the amount of compression and prevent the increase of power when the resistance has reached a limit suited to the quality of the coal, and this is variable at will. To attain this end it is necessary that the working parts should be, so to speak, elastic.

The rear shaft, O (Fig. 4), of the upper levers is capable of sliding in a groove, *a*, and is carried by a piston, *p*, working in an hydraulic cylinder, T, the relations of which are clearly shown in the figure.

The hydraulic cylinder, which is firmly bolted to the bed plate of the machine, is furnished with two valves (Fig. 5), one opening inward and the other outward. If the compressing piston, J, in moving downward, meets with a resistance greater than that offered by the water in T, the valve opening outward permits the water to escape and the piston, *p*, to travel upward, carrying with it the levers I I. The parts ultimately resume their initial positions by gravity, the valve being provided with a spring, and the pressure to be exerted by the pistons, J, can be readily changed by increasing or decreasing the tension of this spring.

By the tension and elasticity given by this apparatus the pressure which it is desired to give the briquettes can be regulated with precision.

In short the compression is made in three motions: first, the upper compressor piston works alone; second, the lower piston rises sufficiently to make the pressure equal on both surfaces; and third, the piston of the regulator entering the hydraulic cylinder starts at the moment when the pressure is attained, and just as the dead center is reached by the cranks.

The correct movement of the mould-table is effected by means of a drum, R (Fig. 3), carrying grooves of a peculiar shape, in which slide the rollers, S (Fig. 2), of which the effect is to begin the motion with no power at the start, but increasing uniformly to the maximum, and returning to the initial degree by inversely similar ratio. The curve representing the motion is composed of two parabolas.

The work of the drum in moving is as follows: The rollers, S S, enter the grooves successively, and are driven forward by their sloping faces. The mould-table stops when the rollers are held in the normal parts of the grooves; it is then held firmly in place by the three rollers, which prevent its movement in either direction.

The skeleton of the apparatus is composed simply of a frame carrying pedestals, of moulding table, of a central guide for the table, pistons, levers, shafts, cranks and winches, the drum and the hydraulic regulator. These are reduced to the most simple form, if we take into consideration the numerous actions they perform.

The moulds are filled by means of an ordinary distributor fed by apparatus for mixing the paste. The finished bricks are thrown on a rocking table, U. or upon an endless band placed directly under the machine.

The spring, *r*, in Fig. 4, serves to bring the lower arms, L L, back to their original positions, after having aided in partially compressing the mixture.

The mould table carries twelve to fourteen moulds, and the pressure which can be obtained is a little over 4000 pounds to the square inch.

Some of the advantages claimed for this machine are: equal compression on both faces, and consequent homogeneity of composition; perfectly formed briquettes, little liable to loss by breakage in transportation; reduction of the motive power to the minimum; and the possibility of having all the parts of the machine directly in sight, and the consequent care which can be taken of them.

These presses, manufactured in France by Biétrix & Co., and by Schüchterman and Kremer in Germany, have come into very general use.

The Yeadon press, manufactured at Leeds, which is of this same general type, is also in use in many parts of the world.

HYDRAULIC PRESSES.

The Révollier (French) and Bodmer (English) were among the earliest hydraulic presses made, and were very effective, but in the earlier ones the cost of production was slightly higher than in other presses. As a type of this class of presses the following description by Dr. Grimshaw of the improved machine built by the Société Nouvelle des Forges et Chantiers de la Mediterranée is given:*

*Journal of the Franklin Institute, September, 1879.

"The briquette machine of the 'Société Nouvelle des forges et Chantiers de la Mediterranée' is shown in two sections, in Fig. 1, Plate XV.* It is a modification of the Mazeline and Cody compressing machine, well known in Europe in this industry. By the patent office classification it would, as now built, be considered as a duplex hydraulic machine, with horizontal mould tables, continuous moulding and successive production.

"It differs from the old type of machine:

"First. In consisting of two separate machines, which can be worked either or both at will, thus permitting one to work at normal belt speeds on half production.

"Second. In employing hydraulic pressure. Thus, while in the Mazeline machines the compression is by steam pistons acting on a lever, and reaches a maximum of 90 kilogrammes per square centimetre (say 1200 pounds per square inch) of horizontal section of the briquette—it varies in the new machine from 100 to 300 kilogrammes per square centimetre of the same section, and without recourse, as we shall see later, to the special pumps, accumulators, etc., which accompany hydraulic machinery of all kinds.

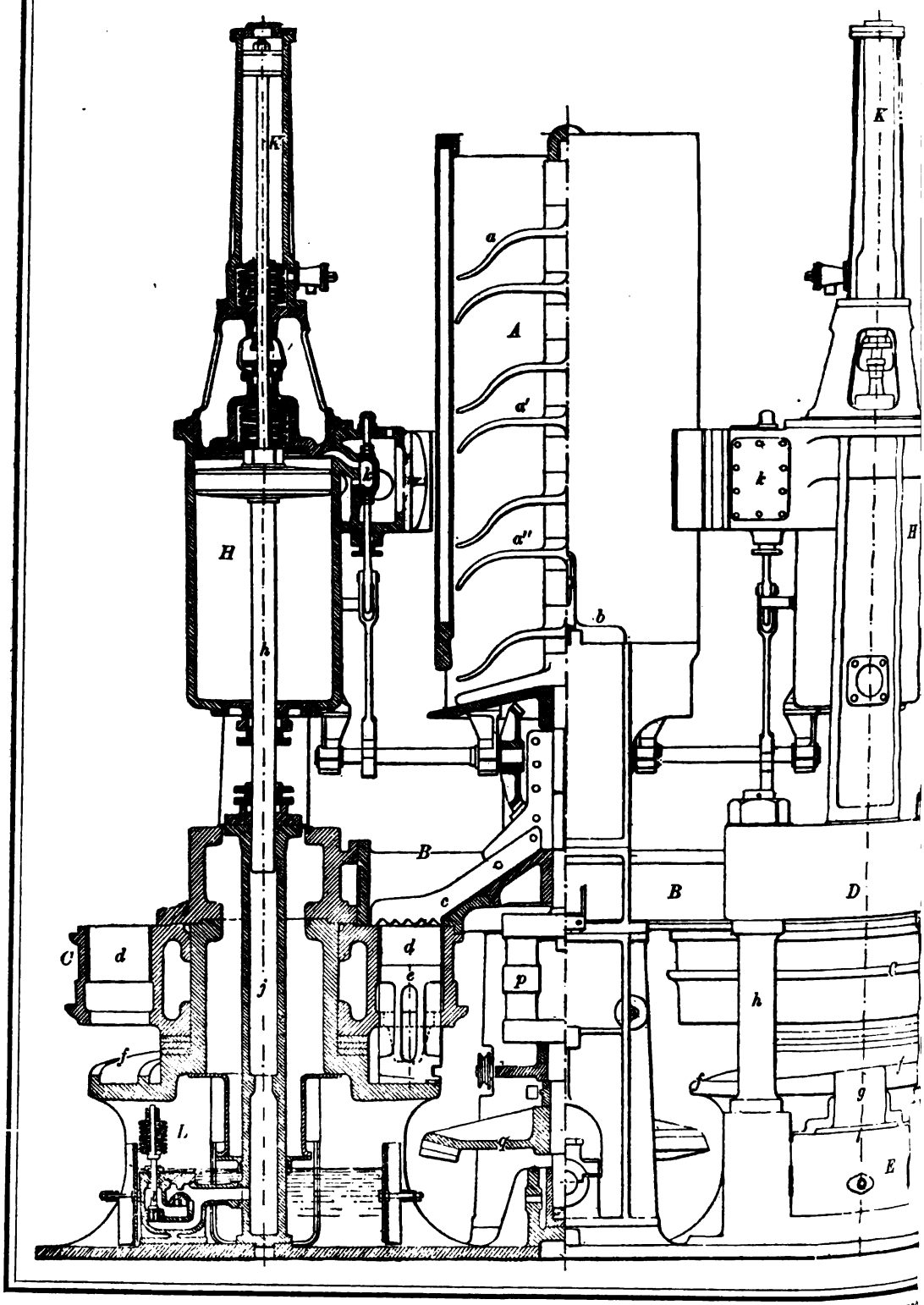
"This agglomerating machine consists of:

"First. *A Mixer* (A). This is a large vertical wrought iron cylinder, in which the materials are brought gradually to a temperature suitable for agglomeration. It is composed of a double envelope, in which circulates steam, which keeps the walls at a high temperature. On the same axis, as the cylinder turns continuously, a vertical shaft, armed with blades, *aa*, which divide the materials, mix them and knead them. Jets of steam are let in at the same time by openings shaped like rose sprinklers, and so placed on the walls as to surround the materials on all sides during the mixing, and to heat them by giving up all the very considerable heat (530 calories). When the material appears sufficiently hot or agglomerant (which the workman can readily see by taking some in a shovel and pressing it with his hands), he opens two doors, *bb*, in the lower side, and the material falls into the distributing apparatus.

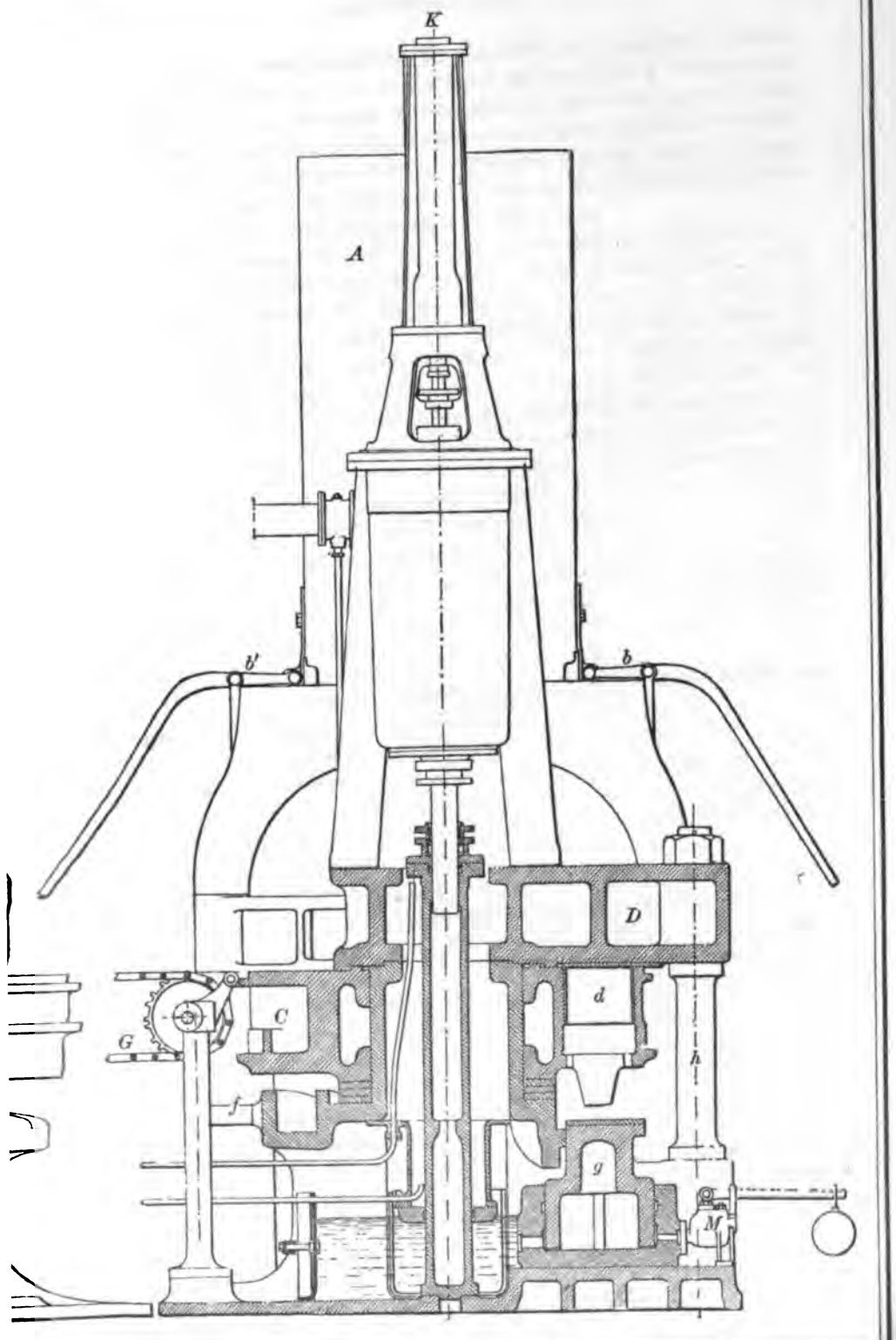
"Second. *The Distributor.*—This serves to distribute the paste into the moulds. It is composed of a cast iron chamber, in which turns a rake or scraper, of which the arms, *c*, sweep the material into the moulds, which pass under the distributor, and are there completely and uniformly filled.

"Third. *Moulding and Discharging Apparatus.*—One on each side of the filler, and under it, are two rotating 'mould tables,' which are heavy disks or plates of cast iron, bearing on their plane faces, near their circumferences, a circle of angular recesses, faced with steel, and correspond-

*Taken from Engineering, November 8, 1878.



BRIQUETTE PRESS



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ing to the form and dimensions of the block or 'briquette' desired. These mould tables have an intermittent motion upon a vertical axis, forming part of the bed plate of the machine, and carrying with them rectangular compressing blocks or pistons placed in the recesses or moulds. These blocks rest upon and slide on horizontal, circular inclined planes, *f*, which form part of the foundation of the machine, and which give to the blocks a rising and falling motion in the moulds.

"Following one of the moulds during a revolution, we note that the mould table is stopped when each mould is under the distributor; and in this position of mould the piston is at the bottom of its course and resting on a horizontal plane. The material, pushed by the scraper of the distributor, fills the moulds completely. The rotating mould table starts off and then stops — the mould is still under the distributor; the piston block has slid along the horizontal part of the track, in case the moulds were not perfectly filled at the first stoppage, the filling continues and is surely finished. At the next movement of the mould table the mould passes under a compression surface, D, the block mounts the inclined plane, and thus lightly compresses the paste. This 'initial compression' is highly advantageous, bringing the paste to a compact condition, and in the case of moist coals (most coals are moist), expressing most of the water. It also saves a good deal of the power required for the heavy compression, as in using the full force of the machine to effect light work only, much force would be wasted.

"The mould rests under the compression table, and the block completes the initial compression by finishing the ascent of the inclined plane, and then passes on to a horizontal plane or track on the level of the hydraulic press. In the next movement of the intermittently rotating mould table, the piston block passes under the press or ram, E, and during the next time of stoppage is forced in by the plunger, *g*, thus powerfully compressing and agglomerating the paste.

"The intermittent movement of the mould table continuing, the mould comes from under the compression plate, the block piston mounts a second inclined plane, and raises the finished briquette in the mould; so that by the time the table has made a semi-rotation, the block is entirely free from the mould, and a "mechanical hand" takes it off the table and puts it on an endless chain, G, to be carried away.

"Fourth. *The Compressor.*—This essential part of the machine consists of a compression plate, D, held by strong wrought iron pillars or bolts, *h*, to the foundation plate, and to the steam and hydraulic cylinders which produce the compression.

"The cylinder, H, above the compression table is a steam cylinder, its piston rod, *h*, serving as the plunger of a hydraulic pump, I, resting on the bed plate. In communication with the pump is the hydraulic ram or

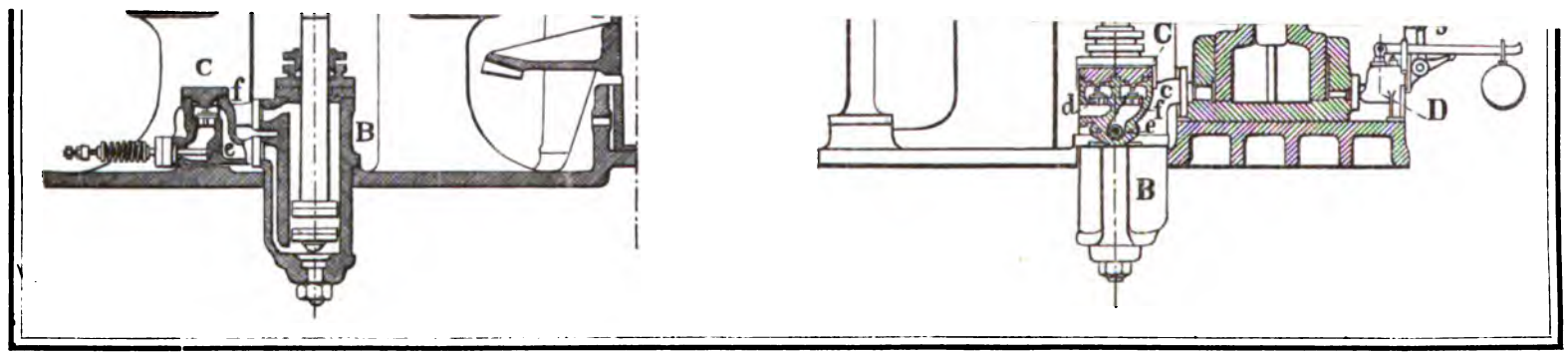
press, E. Above the steam cylinder and on the same axis is a cylinder of lesser diameter, K, having its lower end always in communication with the steam supply pipe, so that there is a constant pressure tending to keep the steam and pump pistons at the upper end of their stroke, and the press ram at lower course.

"The steam cylinder is supplied with a steam chest and a slide valve, K, actuated by an eccentric, having a motion proportioned to that of the intermittently rotating mould table. As each mould block stops under the press the slide valve opens the admission port, and the steam, acting on the upper face of the piston, drives the steam and pump pistons down, and the water pressure transmitted to the ram causes the compression The slide valve then shuts the steam ports and opens the exhaust port; the piston of the small steam cylinder raises the system to its first position. Between the pump and the hydraulic press is a valve box, L, containing two clappet valves, one, *l*, held in its seat by adjustable springs, and the other, *m*, able to lift freely and let the water return.

"The water forced by the pump lifts the spring clappet before acting on the press, so that, in case the distribution of the paste in the moulds is stopped or incomplete, and in consequence the effect of compression is suppressed or reduced, the resistance experienced by the water in lifting the clappet prevents too rapid a movement of the pistons and plungers from causing shocks. The return valve permits the water to pass freely from the press to the pump in the next movement. It is easy to understand that this disposition renders the movements of the organs of compression independent, in a great measure, of the regularity of distribution of the materials in the moulds. In case the pistons arrive at the end of their stroke with some considerable speed, as always takes place at the upper end of the stroke, their momentum is taken up by the spring buffers, *n*, *o*, in the upper part of the large steam cylinder and the lower part of the little one.

"Another part of the compressor is a valve box, M, communicating with a water tank, and containing a safety valve held by a weighted lever, and which valve is lifted when the pressure of water in the hydraulic press passes any given limit. There is a second, or suction valve, which allows water to pass from this tank into the hydraulic pipes to compensate for losses.

"Fifth. *Organs of Movement or Driving Parts.*—The intermittent motion of the rotating mould tables is produced by two pawls acting on cast iron teeth on the crown of the mould tables and corresponding with the moulds; these pawls are actuated by the connecting rods of a crank shaft, *p*, so that each turn of the axis causes motion of one table and rest in the other. The crank shaft is driven by bevel wheels, *q*, and a pulley.



BRIQUETTE PRESS—HYDRAULIC.

The auxiliary apparatus has (as has the main machine) fast and loose pulleys and proper striking gear, and they receive motion from the main driving shaft of the factory. All the transmission is by means of belts, and the tension and the belt lacings or fastenings are arranged so as not to exceed in strength a certain limit; so in case the apparatus is stopped by the presence of a foreign body in the coal or in the pitch, the belt breaks or slips and no damage is done. There are, of course, necessary the suitable boilers and driving engines.

"I gave above the degree of compression which could be obtained. Here is a table of the production for twenty-four hours of the different sizes of this apparatus, the sizes being named after the weight of the blocks produced. It is not very necessary to remind one that the single machine has but one mould table.

Size of machine or weight of blocks.	Production in 24 hours.	
	Single.	Double.
10 kilogrammes—22 pounds	290 tons	580 tons
5 kilogrammes—11 pounds	160 tons	320 tons
2.5 kilogrammes—5.5 pounds	86 tons	170 tons
1.25 kilogrammes—2.75 pounds	48 tons	96 tons

"The machine described compresses its own water as required, but it is evident that if it were desired one could utilize a natural head of water, or draw the water from an accumulator, or from any other source of liquid under pressure. In this way the steam cylinders and the pump are omitted, the hydraulic press being retained and supplied with a distribution chest having a suitable slide valve.

"The mechanical arrangement by which this is proposed to be effected by the 'Société des Forges et Chantiers' gives two successive and increasing hydraulic pressures, independent of the initial wedge pressure given by means of the inclined plane.

"The economy of steam resulting from this arrangement is considerable. In making the calculations from the curves, based on a pressure of fifty kilogrammes per square centimetre, the weight expended per stroke of piston is four-fifths that to obtain the same result with a single pressure; and for a pressure of 100 kilogrammes per square centimetre (say 1375 pounds per square inch), the expenditure is reduced to 20 per cent of that indicated by curve 4; that is to say, a mean economy of two-thirds the steam.

"The new machine is represented in section and elevation in the two figures, Plate XVI. In comparing it with Plate XV, we see that the two steam cylinders (the compression cylinder and the auxiliary steam cylinder) are

replaced by a single steam cylinder, A, of which the piston carries an expansion joint, *a*, and which receives the steam by a double ported slide valve, *b*. The plunger pump is replaced by a piston pump, B, having a valve chamber, C. Finally, for the buffers in the steam cylinders, there is substituted a single box containing a rubber block, D, in full sight, and controlable while the machine is running.

"The section of the pump piston is such that with the steam acting above the steam piston, the pressure of the water under the pump piston corresponds to the first rectangle in broken lines. The section of the pump piston rod is such that the pressure of the water in the pump will be the maximum desired, if this steam acted as the plunger of a hydraulic pump. This pump is in communication with the hydraulic press by the passage, C.

"Suppose the steam admitted by the upper port of the slide valve, the pump piston descends and compresses water in the press at the first pressure. At the same time the space which would otherwise be left void above the pump piston is kept full by means of a valve, *d*, in communication with a supply tank.

"As soon as the resistance of the press passes what we should call the first pressure (that is, the first hydraulic pressure) on the paste, the valve, *e*, held by a suitably adjusted spring, opens; the water, under pressure (I object to the use of the expression compressed water) passes in part from the other side of the piston, shuts the suction valve, *d*, and we have the conditions of a hydraulic pump having a plunger of a diameter equal to that of the piston rod. The compression is thus continued with this second or maximum pressure. When the resistance of the press attains this maximum, the safety valve, D, opens, the press stops, and the compression is held until the slide valve closes the steam port and puts the upper part of the steam cylinder in communication with the lower; the steam piston is then raised to the upper end of its stroke by a pressure due to the difference in areas of the two piston surfaces. The pump piston is thus raised; the water passes from the upper to the lower side by the valve, *f*. Part of the water in the hydraulic press also returns under the pump piston, the rest being discharged by the safety value, D. which is for this purpose raised by the lever, *g*, suitably actuated.

"It is nearly useless to add that by tightening the springs of the valve, *e*, we increase the initial pressure, and thus we can so control the disposition of the partial rectangles upon the curve representing the resistance on the hydraulic press, as to effect the greatest convenience and economy in work, and to adjust the machine to the material it may be working.

"In the case of the briquette machine supplied by a constant head of water, and to which I referred above, the arrangement adopted by the 'Société des Forges et Chantiers' is based upon the same mechanical principle.

"The steam cylinder is of course omitted, and the hydraulic press, as described, is replaced by a double-acting press, the two parts of which are put in communication by a valve chamber with a spring poppet and a return valve."

STEAM PRESSES WITH OPEN FORMS.

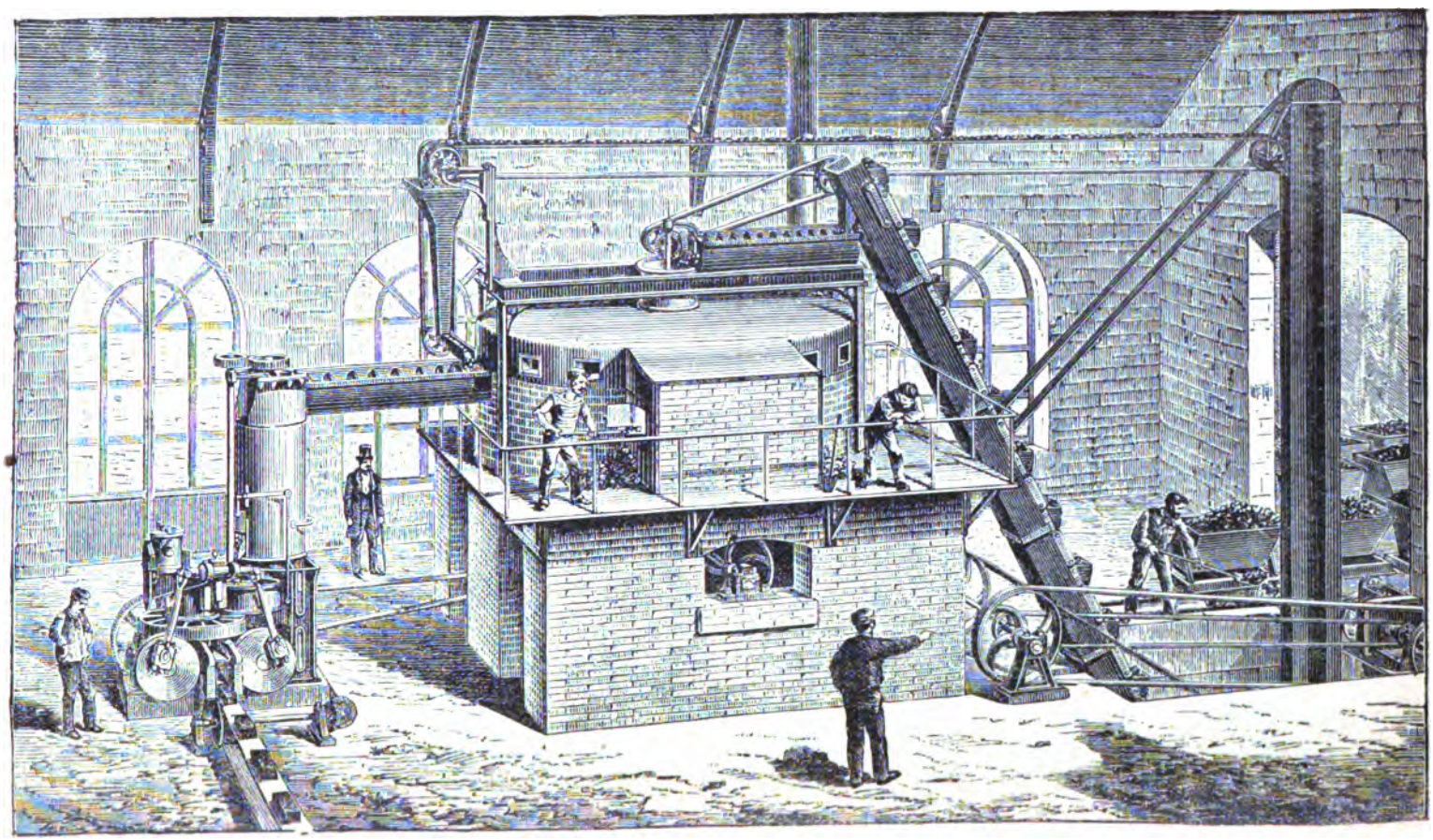
The general principle of the continuous presses consists in compressing the plastic material in a form open at both ends by means of a stamp moving backward and forward. As the stamp moves backward a certain amount of the mixture to be compressed falls into the mould; during the forward stroke of the stamp this material is forced against that previously pressed, by which means this is driven still further forward toward the open end of the mould, and then, by automatic appliances or knives, cut into such number of briquettes as the stroke of the stamp will allow. In compressing, the stamp has no other resistance than that offered by the friction of the briquette mass in front of it. This friction is very considerable, and increases with the length of the mould.

The principal machines operating under this system with use of bond in compressing are the Evrard, which uses soft pitch as an agglomerant, and manufactures briquettes of cylindrical form, and the Bouriez, which is built on the same principle, but for brick-shaped briquettes, and is in use in many places in Belgium and Germany, including the cast steel establishment of Krupp.

The advantages claimed for machines of these systems are moderate cost and great simplicity of plant; but a greater power is required for operating them than for machines with closed forms.

The machines for compressing brown coal without bond are also constructed under this general principle.

PLATE XVII.



THE PROCESS OF BRIQUETTING.

Having given the details of the different methods and apparatus employed in the preparation of compressed fuel with the use of a bond, it may not be amiss to give in a single view a general idea of the arrangement and working of a briquette plant. This will be seen by reference to Plate XVII.

This process begins properly after the preparation by sorting, pulverizing, washing and drying, or otherwise cleaning the coal.

The fine coal is dumped into the pit nearest the drying furnace. It is raised by elevator buckets and emptied into a trough, through which it is carried by an endless screw to the center of the drying furnace. Falling upon the revolving table inside the chamber, the rakes move it continually toward the outside as the table turns, until finally it is discharged into the trough connecting with the agglomerator.

The pitch is pulverized, raised by an elevator, and carried forward by an endless band to a hopper, whence it falls into the same trough in which the dried coal has been discharged. The hopper contains the arrangement for regulating the amount of pitch to be added. The pitch and coal are then carried forward together by the endless screw to the mixing chamber, where the mixture is perfected by proper mechanical means and the degree of heat necessary for successful agglomeration secured by a steam jacket. The paste then falls upon the distributing table from which the moulds are filled, the moulding table revolves until the mould comes between the dies or stamps. The compression takes place, and the finished briquette, after a quarter revolution, falls upon an endless band, and is carried away for drying and storage or shipment.

In drying such briquettes it is advisable not to pile them more than three high while they are yet warm, as in such case sufficient heat is sometimes evolved to cause their ignition. After they have thoroughly cooled there is no further danger of such ignition.

COST OF BRIQUETTE PLANTS AND OF THE MANUFACTURE OF BRIQUETTES.

The prices quoted by the manufacturers of the various systems of presses and machinery differ widely. Preissig gives as the cost at factory of complete plants the following figures, which are approximately correct, some of them having been revised and present quotations used:

Name.	Weight of each briquette.	Production per hour. Tons.	Price.
Bietrix	6½ pounds.	3.6	$7,500 00
Dupuy (2 presses)	6½ pounds.	5.0	7,000 00
Couffinhal	6½ pounds.	5.0	12,500 00
Bietrix	11 pounds.	6.0	12,000 00
Dupuy (2 presses)	11 pounds.	7.0	8,500 00
Mazeline Double	11 pounds.	13.0	20,000 00
Couffinhal	11 pounds.	7.5	18,500 00
Yeadon	11 pounds.	5.0	6,250 00
Middleton-Detombay	22 pounds.	6.0	13,000 00
Couffinhal	22 pounds.	12.0	23,000 00
Bouriez	.....	5.0	11,250 00
Evrard	.....	5.0	12,600 00

In addition to these prices there would be freight on from forty to one hundred tons of machinery from factory to destination, and the cost of erection of building and setting up machinery.

These prices do not include the machinery for cleaning the coal, but do include pulverizers for coal and pitch.

As the amount of pitch used is variable, only a very general statement can be made regarding cost, which as given here does not include expenses of management nor real estate.

In Belgium the Détombay presses use 8 per cent hard pitch at a cost of $10 per ton, and their fine coal costs $1 per ton. Total cost, including labor, fuel and oil, $2 per ton of briquettes.

By the Couffinhal system, employing nine men and boys, and using 7 per cent pitch as agglomerant, the cost, exclusive of cost of fine coal, is 85 cents to $1 per ton.

The detailed cost per ton by the new machines, according to the statements of the various briquette manufacturers, is as follows:

Wages of workmen:

England	10 to 18 cents.
France	10 to 15 cents.
Germany	10 to 12 cents.
Fuel, oil, repairs, etc	7 to 8 cents.
Interest and depreciation	6 to 10 cents.

Pitch for bond:

England, 6 to 8 per cent.

France, 4 to 8 per cent. ..... 38 to 100 cents.

Germany, 6 per cent..... 60 to 70 cents.

BRIQUETTING WITHOUT BOND.

As has already been stated, there are two entirely different methods in use for the manufacture of artificial fuel from brown coal without the use of a bond. The fuel produced by these is known respectively as nass-press-kohlen, or water-pressed coal, and darr-press-kohlen, or briquettes.

WET PRESSING.

The simplest of these is the manufacture of nass-press-kohlen, but the fuel produced, though more stable than the earthy brown coal of which it is made, is suitable principally for domestic purposes. The coal used in this is the earthy brown coal containing a variable amount of "schweelkohle." The presses are run only during the warmer months, as freezing would destroy the briquettes. The mining of the coal is continued through the winter, however, and the great piles of coal are kept wet to prevent spontaneous combustion. The coal is thoroughly mixed and carried, by either inclined plane or aerial cable conveyance, to the room above the press. Here it is again wetted and mixed, and passes into the hopper between two heavy rollers, which reduce it to fine powder.

The press, which is very similar to a brick machine in character and operation, is illustrated in Plate XVIII.

It has a compressive force equal to five atmospheres.

The bricks are cut as the moulded block comes from the press, and then arranged on shelves in long open sheds, where they remain until they are dry, which takes from four to five days to as many weeks. When they first come from the press the bricks have the following dimensions:

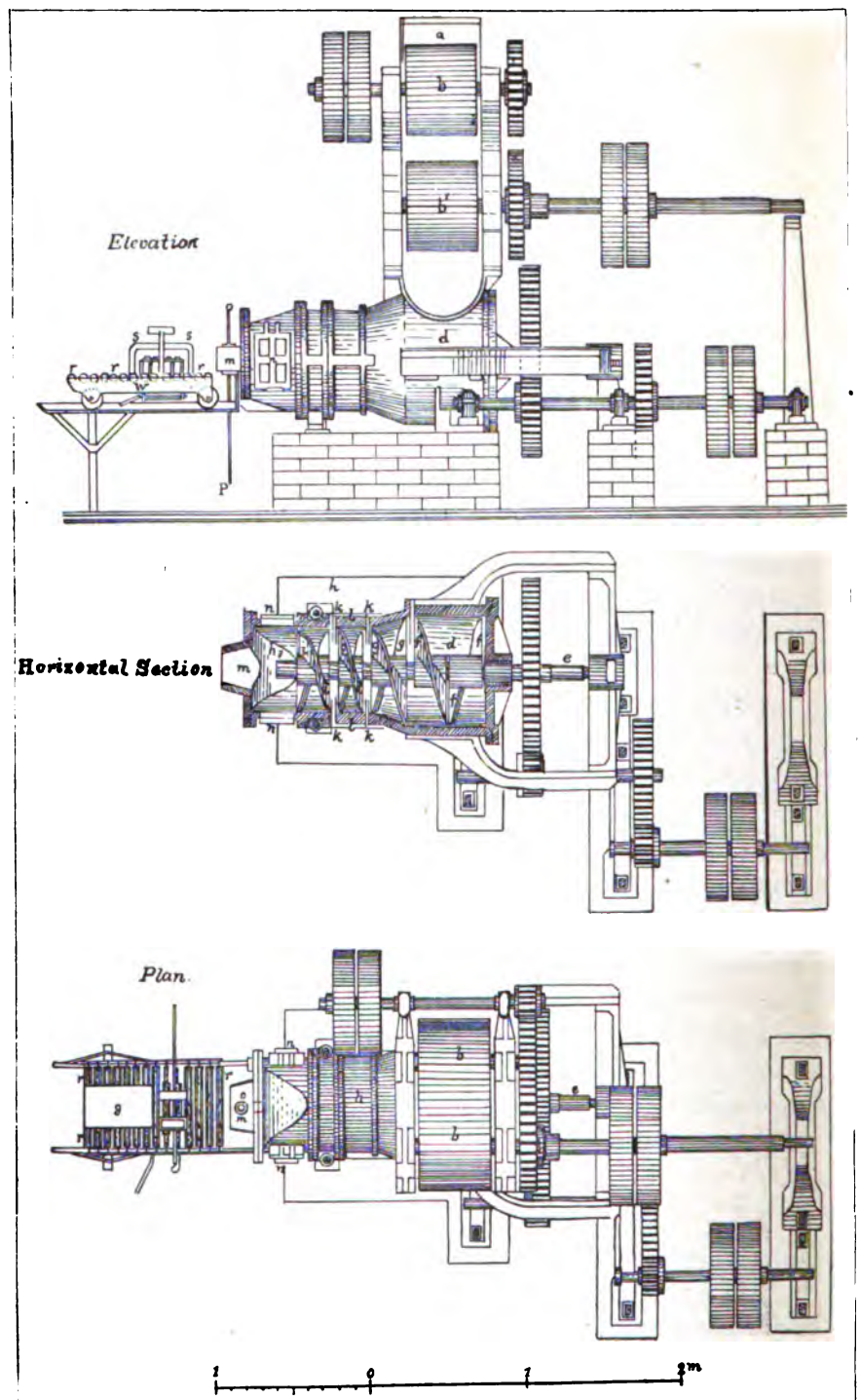
65x118x200 mm.; $2\frac{1}{2}$x$4\frac{3}{4}$x8 inches.

In drying they shrink to the following:

60x115x190 mm.; $2\frac{1}{4}$x$4\frac{1}{2}$x$7\frac{1}{2}$ inches.

Their weight, which is in the freshly formed bricks about five pounds, is reduced by drying fully one-half, so they do not exceed two and a half pounds each.

PLATE XVIII.



PRESS FOR COAL BRICKS (Nass-press-kohlen).

A press producing 90,000 bricks in ten hours requires an engine of thirty-five horse-power, and there are employed in mining the coal and operating the plant as many as 100 to 130 men.

Briquettes of this character are in demand for use among the farmers, and wherever a low priced fuel is needed and no great heating power required. In 1890 there were forty-five factories of this character in Germany, and the production for the year was 340,000,000 bricks, which were worth at the factory $2 per thousand.

DRY PRESSING.

The manufacture of briquettes by heavy pressure without the use of bond has, up to the present, only proved applicable to certain kinds of brown coal, and to those bituminous coals which are of a decidedly caking character, in which the heat evolved by compression causes the development of sufficient bituminous matter to cement it.

The brown coal which lends itself most readily to this method of treatment is the earthy or common brown coal which occurs in such abundance in the province of Saxony and on the Rhine.

As it is mined the coal is a mixture of earthy or common brown coal, with more or less "schweel" or tar coal and lignite. The deposits are of great thickness, twenty and even thirty feet not being uncommon, and even much greater thickness being found. As they usually lie near the surface, they are worked by open mining. The coal is roughly separated, as mined, into that which is intended for the manufacture of tar at the schweelerie, and that which goes to the briquette press. From the mine it passes by underground or overhead channels to the place of its destination, and is there again culled before being used.

The coal as it comes from the mine is, for the most part, of an earthy, friable nature, smeary, brownish-black in color, and contains from 40 to 60 per cent of moisture. Before it is compressed the excess of water must be driven off by evaporation.

The process of dry briquetting may be divided into

(a.) Pulverizing and mixing.

(b.) Drying.

(c.) Pressing.

(a.) PULVERIZING AND MIXING.

The coal as it arrives in the mine cars is raised by platform elevators to an upper story, whence it passes through a series of breakers, crushers, rollers and sieves until it reaches the ground level again in a mass of uniform grain and thorough homogeneity.

(b.) DRYING.

After pulverizing and mixing, the coal is again lifted by bucket elevators to the upper stories to the chamber from which it passes into the drying apparatus.

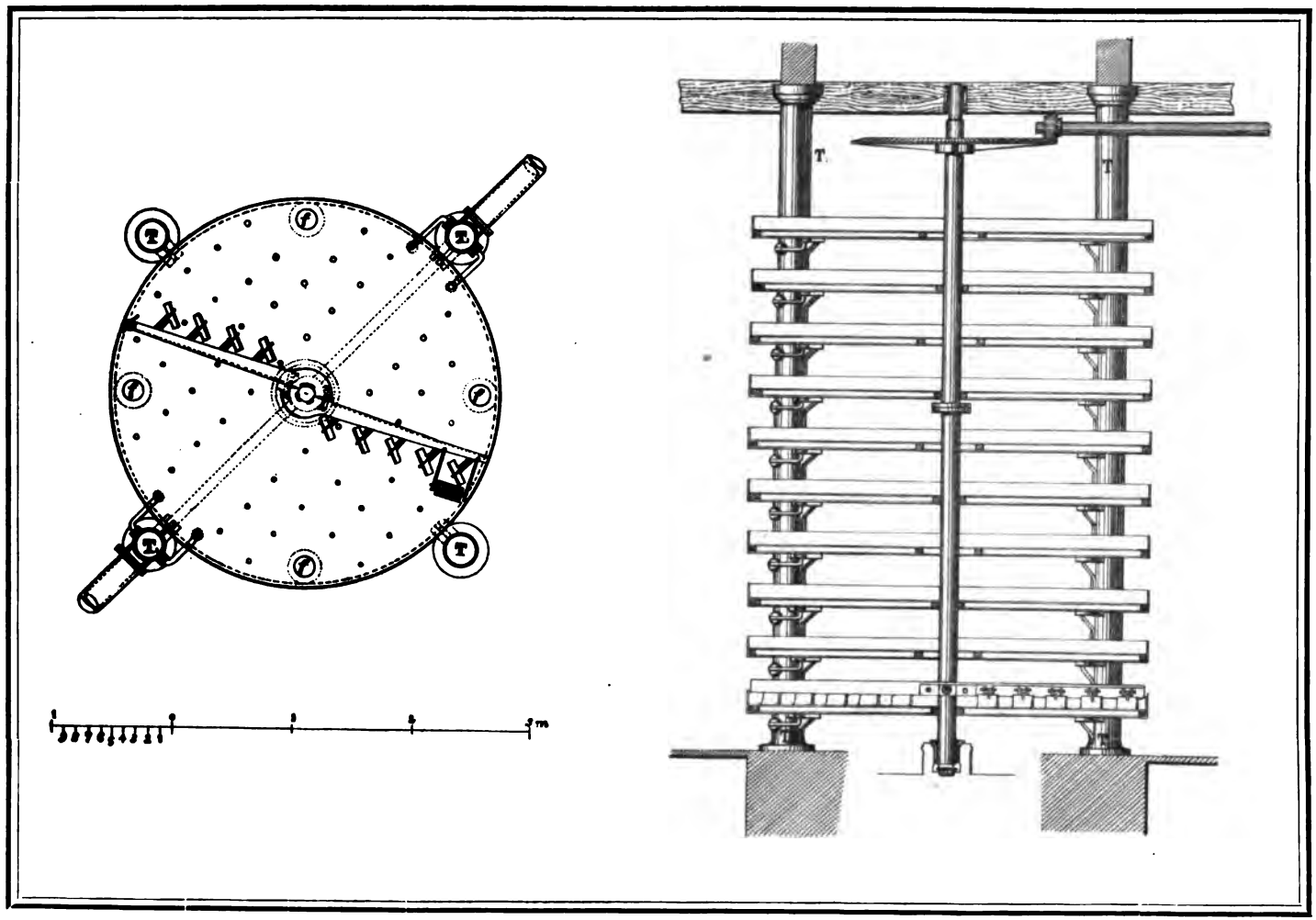
Care must be taken in the dessication of the coal; first, that the drying be only carried to that point which will leave the coal in the best condition for briquetting. This differs with different coals, but it is usually considered necessary to leave in the coal from 10 to 20 per cent of moisture. In the second place, this desiccation can not take place at too high a temperature, because then the coal itself would suffer more or less decomposition. As the usual amount of moisture contained in the brown coal of the province of Saxony, as it comes from the mine, is from 46 to 60 per cent, according to Wendlandt, it is evident that the drying is a very important part of the briquetting operation, since, in order to obtain 100 tons of briquettes, from 125 to 200 tons of brown coal must pass through the drying process.

Many different arrangements have been tried for this purpose, and many of them are still in use among the briquette factories of Germany. Some varieties are shown in the cuts on Plates XIX, XX, XXI.

The large amount of water to be evaporated, and the danger to be avoided of spontaneous combustion or explosion in the finely divided heated coal, have finally brought into most general use such apparatus as effects the drying of the coal with least danger of ignition from coming in direct contact with the heated air or steam used in drying.

The apparatus in use is of two general types. In the first the movement of the coal is effected by mechanical means, and in the other it is automatic. They are further divided by the manner of heating, which may be by direct firing, by heated air, or by steam, or by a combination of these.

PLATE XIX.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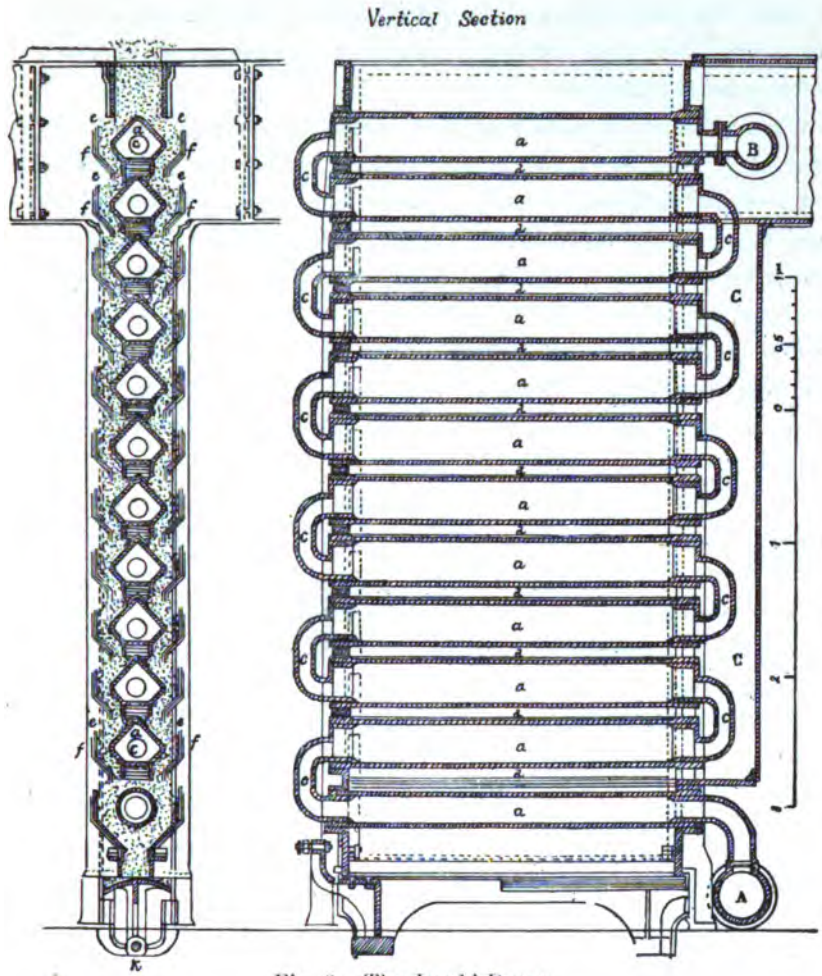


Fig. 6. The Jacobi Dryer.

The Jacobi dryer, shown in Fig. 6, belongs to the second class. It consists of a series of steam pipes, *c*, surrounded by three or five-sided metal chambers, *a*. The metal boxes, *d*, are filled with heated air from a blast, and the working together of this heated air and the heat from the steam pipes dries the coal as it passes one after another of the chambers in its descent between them and metal guides, *f;* the water evaporated finds exit at *e*. There are several dryers of this general type, varying in the arrangement of the different parts.

Of the drying apparatus using steam exclusively and securing the continuous motion of the coal by mechanical means, there are two distinct

types — the plate dryer and the tubular oven — with several varieties of each kind, but their differences consist in the manner of applying the same general principles.

PLATE DRIERS.—These consist of horizontal plates or tables of iron having a diameter of twelve feet or more, ranged one above the other in a vertical series of 10 to 20. These plates, when intended solely for drying by steam, are made of wrought iron with double walls, and the space between the walls of each is filled with steam, which is admitted to them through two of four hollow columns, T, the other two serving to convey it away from the plates, through the central axis by means of suitable openings, *a*. These plates have openings, *f*, arranged alternately at the center and circumference for the descent of the coal from one to the other. (Plate XIX.)

Above each plate there is a kind of rake with broad teeth for keeping the coal in motion. These rakes are attached to the central shaft and revolve with it, and the teeth are so arranged that on one plate the motion of the rake moves the coal from the circumference of the heated surface of the plate to its center, where it falls through the openings to the plate beneath, the rakes of which move it from the center toward the circumference again. In this way it passes from one plate to the other until it reaches the bottom and finds an exit in a dried state.

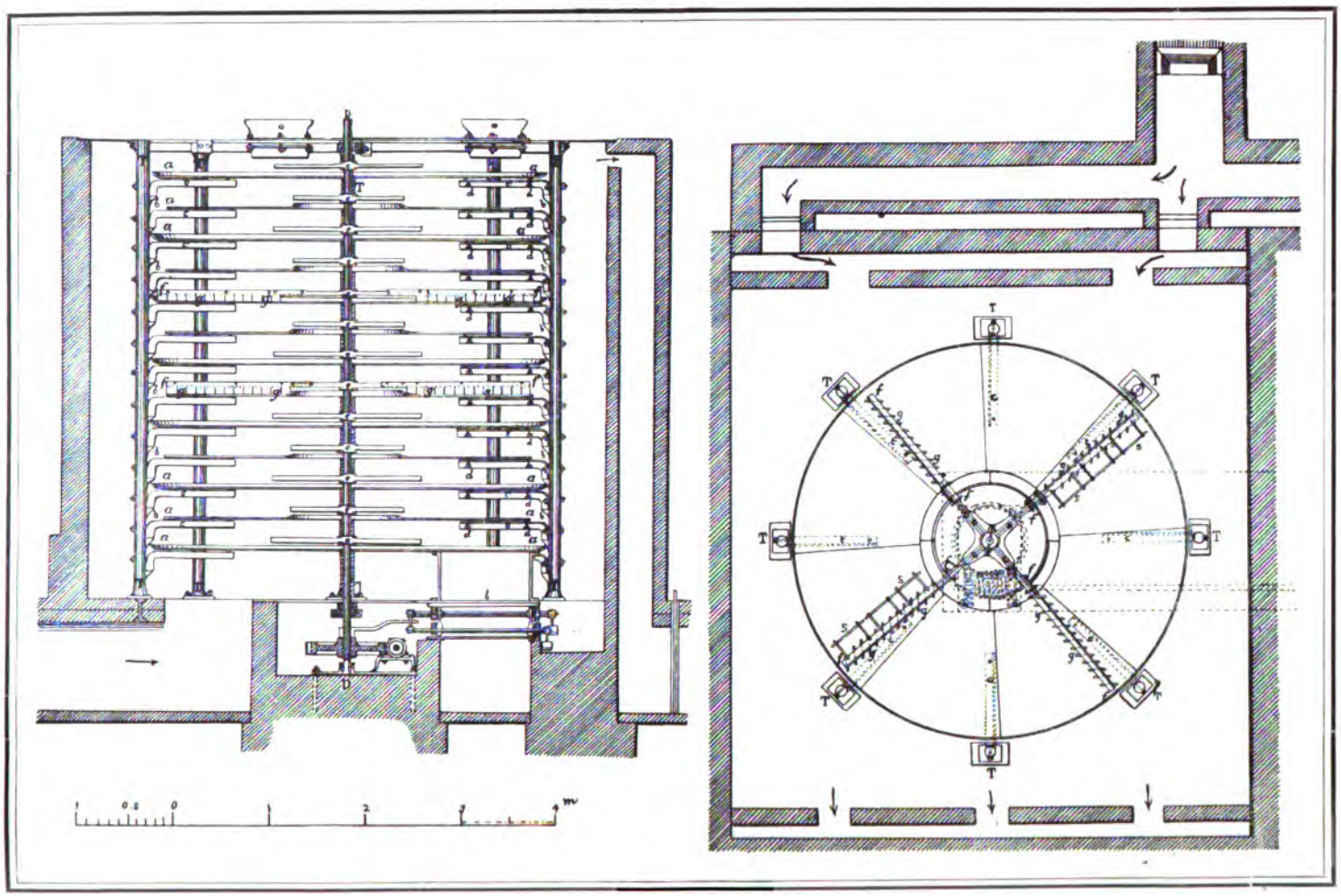
In ovens of more recent construction the plates or tables are enclosed in a sheet-iron cylinder, or walled in, by which their efficiency is increased over 20 per cent. Openings are left for admission of air and for exit of the evaporated water.

The motion of the central axis is secured by a shaft and cog wheels as shown in plate, and the dried coal is removed by means of endless screws and elevators to the store room or direct to the briquette press.

Such a drier of latest construction, with seventeen plates will produce 27.5 tons of brown coal containing 20 per cent moisture from a raw coal containing 46 to 50 per cent moisture, in twenty-four hours. The steam employed in drying is generally the exhaust from the engine, although in some instances steam direct from the boiler is used.

TUBULAR DRIERS.—These are sheet iron cylinders, eighteen to twenty feet in length, over six feet in diameter, and carrying about 200 tubes,

PLATE XX.



RIEBECK DRIER.

which contain the lignite to be dried. The cylinders are placed in an inclined position, the length of the cylinder and the angle of inclination being governed by the amount of moisture to be evaporated from the coal.

In the Schulz apparatus the axle is formed of two hollow cones, which taper toward the middle of the cylinder. These cones have their surfaces perforated and the steam from the boilers or exhaust from the engines is let into the cone at the upper end of the cylinder and into which it escapes through the perforations. After passing around the pipes it passes back into the lower cone and finds exit to the chimney.

The coal is fed into the tubes by suitable appliances from a hopper above, and the cylinder is filled with steam, which carries the process of evaporation to the point at which it is best for briquetting. The entire cylinder is slowly revolved by machinery, and the drying is perfected as the coal, which fills each tube about half full, passes from one end of the cylinder to the other. The expulsion of the aqueous vapors developed by evaporation is accomplished by means of the draught of a chimney about thirty feet in height.

The Schulz drier is recommended for many varieties of pulverulent brown coals, and more than seventy of these cylinders are now in operation in different parts of Germany. They have a capacity of 40 tons per day, and cost in Germany (without buildings or power) $8250.00 each. One of its chief recommendations is its freedom from explosions.

Direct Heating.—In the fire plate ovens of the Riebeck pattern, as shown on Plate XX, we have a series of cast iron plates about 13 feet in diameter ranged one above the other in a series of 15 to 17. These are walled in with masonry, making them much safer than the more open forms. An axle in the centre carries the same arrangement of rakes for moving the drying brown coal that has been described under the steam plate oven. The brown coal is fed from the top, and in the ovens of newer construction the gases of combustion pass from the furnace to the top of the oven, so that they reach the coal containing the greatest amount of moisture first. From here they pass downward over the plates and brown coal, carrying with them the steam from the drying brown coal, and both find exit through the chimney. These driers are especially recommended for brown coals having little bitumen, like the earthy brown coals of Saxony, where a high heat is needed to develop that con-

stituent for the purpose of briquetting without bond. They are not well adapted for fatter brown coals, and require considerable care in their operation.

Leuterts' compartment oven for heating by direct firing is shown in Plate XXI. Its outside dimensions are, length, breadth and height about twenty-four feet each. It is divided by walls into four compartments, and in each compartment there are two divisions, each consisting of four perpendicular prismatic chambers. These chambers contain a series of metal plates bent at an angle of 145 degrees, placed alternately, so that the coal falling from above, by its own weight, has a zigzag motion. The burning gases pass from one compartment to another through suitable openings in the direction shown by the arrows.

Each kind of drier has its own advantages, and is applicable to some certain kind of coal with better effect than with others, and in a quest for that best suited for any particular locality the question of the character of the coal has greatest weight in selection of the drier.

Many other systems or patents are in use in Germany, but the types here figured or briefly described are sufficient to show the general principles of all.

The capacity of such drying ovens as I have described is from ten to forty tons of dried coal each per day. They cost from $2000 to $3000 and upwards each.

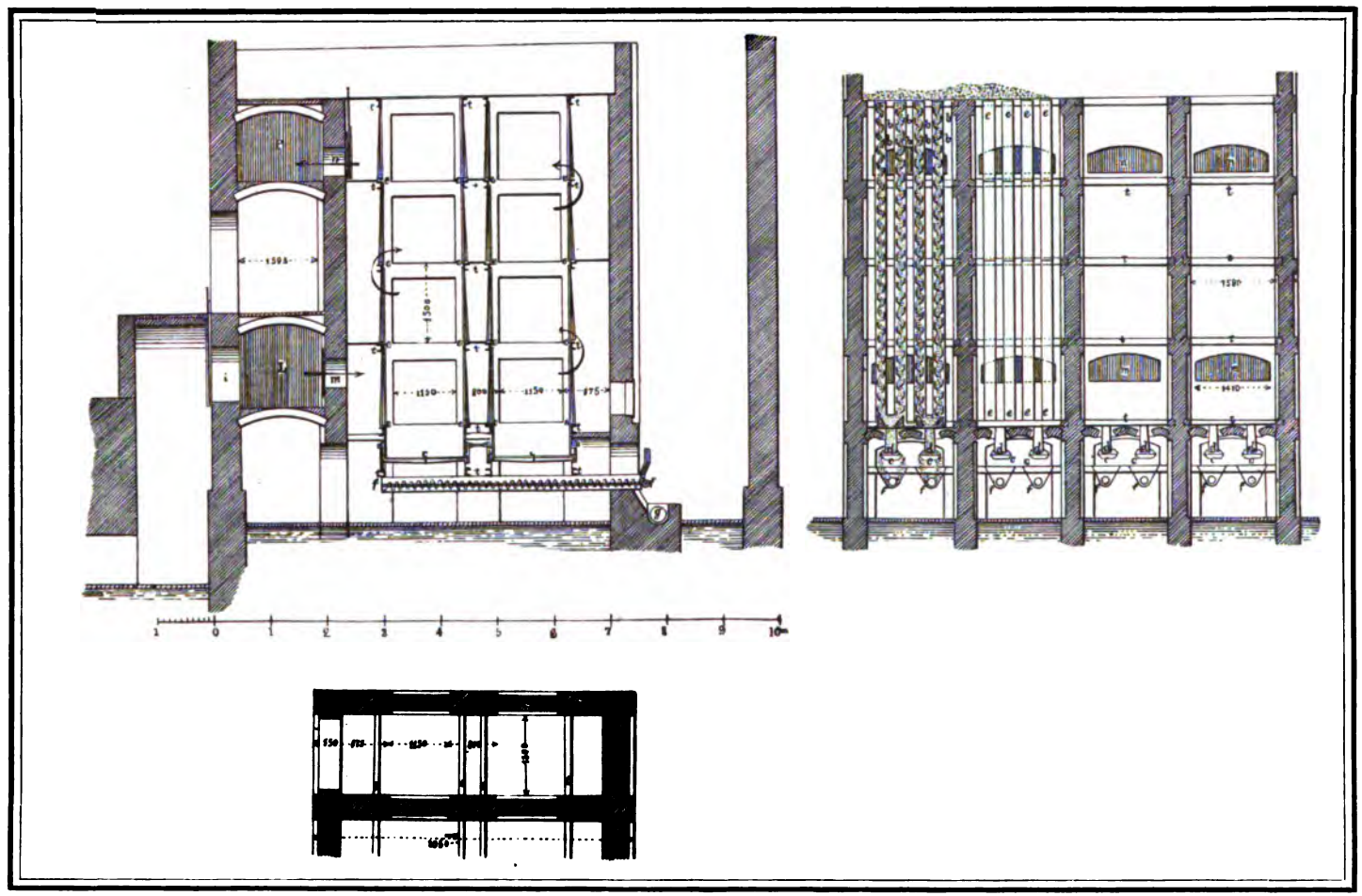
It has been found in practice that the limit of water contents in a brown coal intended for briquetting by this method should not be less than 10 per cent nor over 20 per cent, the exact amount varying with the character of the coal. Dryer coals than these do not, as a rule, make good briquettes. For this reason some of the Bohemian brown coals can not be used in this way, but at Königsberg a. d. Eger a factory was erected by Preissig which is being worked successfully.

PRESSING THE DRIED COAL.

The presses in use for pressing the coal after drying are all of one character, and belong to the class already described under "open form presses." The engraving and sections of the Exeter press will give a better idea of its operation than can be given by a description.

In this machine, shown in Fig. 7, the dried coal enters the press through the hopper, *a*, and passes down to the mould, *h*. The mould,

PLATE XXI.



LEUTERTS COMPARTMENT OVEN. *p. 180*

which is of hardened steel, is made in four pieces, and is held in place by the screw *e*, which is tightened to the proper tension by the wheels *f* and *g* on the retaining plate, *d*.

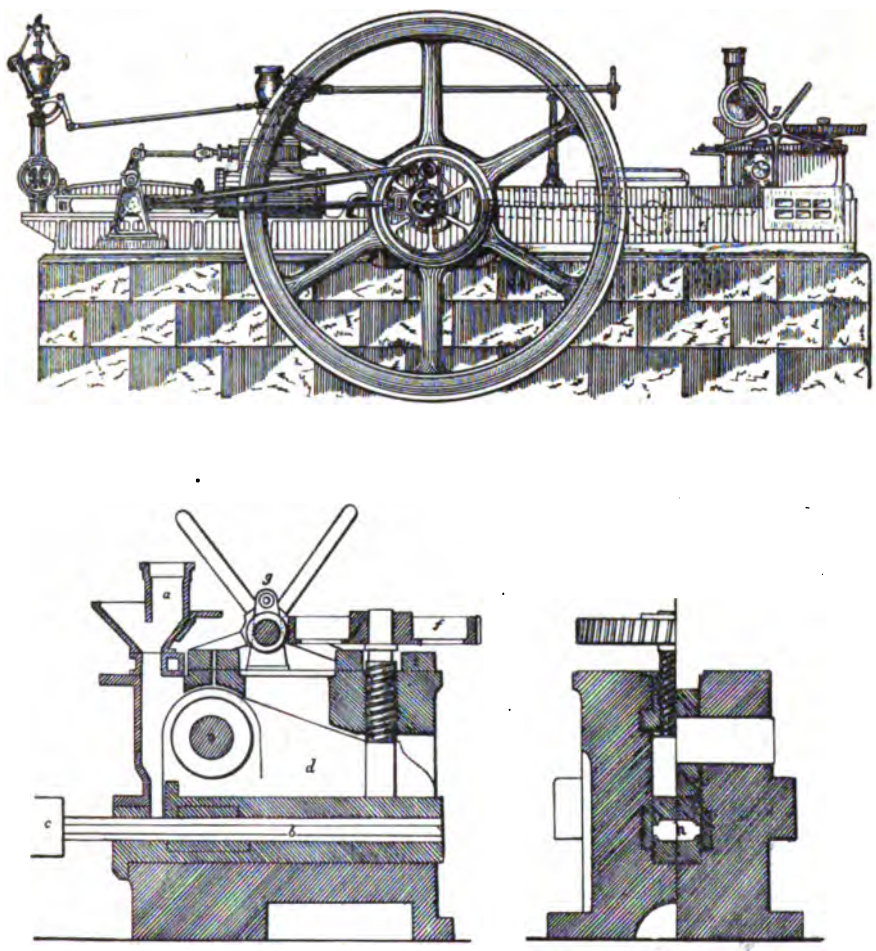


Fig. 7. The Exeter Press.

As the plunger or stamp, *b–c*, is drawn back, the requisite amount of coal falls into the mould and is compressed by the forward stroke of the stamp against the briquettes left in the mould by the former stroke.

The engine has a cylinder 17¾ inches in diameter, and 26-inch stroke, three-fourths filling under steam pressure of five atmospheres, and is regulated by throttle valves. The stamp has a section of about 16 square

inches, and has a stroke of 6 inches. Its backward stroke is 6 inches, and it goes forward 3¾ inches without pressing. The strokes are from 65 to 80 per minute, and a briquette is pressed at each stroke. The power developed in the stroke is from 1200 to 1500 atmospheres in an engine of the size given. In those last built the power of the stroke has been increased to 1800 atmospheres.

The details of the operation of a plant using drying ovens of the tubular pattern and two such presses as the above are as follows:

The raw coal which is required for making briquettes is brought in skips on an inclined plane, by an endless chain, to the second story of the dressing—i. e., the wet coal—house, where the skips are discharged into a hopper. Beneath this hopper there is a feeding apparatus which brings the coal in equal quantities to the breaker, by which the larger pieces of the raw coal are to be crushed. From this breaker the coal is brought onto a shaking apparatus, which is fitted at the upper end with a fine meshed sieve, through which the fine coal falls into the elevator by means of a guide, whereas the larger pieces passing on fall through the second rough sieve and are crushed by the rolling mill—fine rollers—to the degree needed for making briquettes. This also falls, finally, through a guide to the elevator. The pieces of wood (lignite) which are found in the raw coal and can not be crushed, slide over the shaking sieve and fall into a car which is put beneath. These cars, when filled with these pieces of wood, are brought thence by the lift over to the fires of the steam boilers. The elevator raises the fine coal up to the highest story of the wet-coal house, throws the coal on a shaking sieve, which sifts out the small pieces of wood and other things unsuited for the manufacture which may still remain in it, and these then fall through a pipe into a hopper, from which they are also brought to the fires of the steam boilers. The coal which has fallen through the upper shaking sieve is collected in a hopper, and from this it is brought, by means of cars, to the storage room above the driers, from whence the coal is to be distributed over the hoppers of the driers.

The pipe drying apparatus is an inclined boiler, which lies in spherical bearings on I girders; the drier is put in revolution by a toothed gear. Through the axle of the boiler, which is hollow, the heating steam, i. e., the exhaust steam of the presses and of the steam engine, comes into the boiler and surrounds the pipes through which the coal slides. Each boiler

contains 240 drying pipes of about 100 mm. (4 inches) diameter and 6400 mm. (21 feet) length. The coal slides through the drying pipes on account of the inclined position of the drier, during its rotation, and is thereby properly dessicated. The water evaporated by this means escapes through the chimney into the open air. The coal dried by the driers falls into a conveyer, common to all driers, and is brought by it to the last rolling mill and is again sifted and crushed. The coal is then brought by a second conveyer to the supply rooms, which form the cooling hoppers over the presses.

These presses make from 80 to 90 revolutions per minute, and at each revolution a briquette is made. The thickness of the briquettes can be changed by means of a worm wheel at the end of the presses. The press also moves the finished briquettes in iron channels to the loading spot, generally about 100 yards from the press.

The cost of plant and operation in Germany, is stated to be as follows for factory with three presses and suitable drying apparatus with a capacity of 120 tons per day:

PLANT.

Land, building and working capital	$ 67,500
Machinery	75,000
Total	$142,500

COST OF PRODUCTION.

Based on output of 30,000 tons per year, current rates of wages and materials, and raw brown coal at 50 cents per ton:

Coal	$16,000
Wages	8,000
Repairs, dies, etc	2,500
Lights, oil, packing	3,000
General expenses (management)	6,000
Insurance	1,500
Depreciation, 5 per cent	6,500
Sundries	2,000
Total	$45,500

The laborers required are: Day shift — 2 engineers, 1 stoker, 1 pressman, 1 blacksmith, 16 laborers (five of whom may be boys). Night shift — 2 engineers, 1 pressman, 1 stoker, 10 laborers (five of whom may be boys).

The selling price of the briquettes at the works is $2.25 to $3 per ton.

CHAPTER VI.

GEOLOGY OF THE BROWN COAL DEPOSITS OF TEXAS.

The Tertiary deposits of the gulf slope of Texas, in which the brown coals occur, occupy a belt of country sub-parallel to the present gulf coast, stretching from Red River to the Rio Grande. This belt has a length of 650 miles, and its greatest width is about 200 miles.

It covers in whole or part eighty-four counties, and has an aggregate area of nearly 60,000 square miles. The brown coal beds have not been found everywhere within this area, but their existence is known in more than fifty of the counties, and in a large number of them the deposits are workable.

The accompanying map gives the general boundaries of the brown coal area of this Tertiary belt, the locations of many of the outcrops known to the Survey, and of all the mines now in operation.

Owing to lack of topographic maps covering any considerable portion of the area, to the character of the rock materials, and to the general flatness of much of the region underlaid by the Tertiary deposits, it has been almost impossible to form a complete section of the formation, or to secure sufficient data for its final separation into series and correlation with other localities.

The following arrangement may be taken as representing our present state of knowledge regarding the Eocene series, which contains the greater amount of the deposits of brown coal.

Eocene.	Fayette Division.	Brown coal bearing.
	Yegua Division.	
	Timber Belt Division.	
	Basal Division.	

BASAL DIVISION.

This division embraces the Basal beds or Wills Point clays of Penrose.*

* The descriptions of the Tertiary formation and its brown coal deposits are taken from the various reports of the Geological Survey and notes of some of the geologists, supplemented in places by my own observations.

THE WILLS POINT SECTION.—The Basal beds consist of a stiff laminated clay, yellow, gray, blue, or bluish green in color, frequently interbedded with seams and laminæ of sand, containing many concretionary masses of non-fossiliferous gray limestone, which are much cut up by veins of brown crystalline calcite, and vary in size from a few inches to six feet in diameter. They are generally of a flat, elliptical shape, and of a gray color. While occasionally occurring in the upper brown clays, the bowlders are mostly imbedded within the gray sands of the formation near the contact of the lower beds with the Cretaceous. Numerous similar bowlders occur in Muddy Cedar creek bottom, about half a mile northwest of Elmo; also east of Elmo on Walnut creek; also imbedded in clay on the Goschen road, two and one-half miles south of Wills Point; and on the south side of Allen creek, four and a half miles southwest of Wills Point, they are found imbedded in a stratified yellow clay similar to that found on a hill about a mile east of Rocky Cedar. East of Wills Point the calcareous bowlders imbedded in yellow clay occur at several places scattered over an extent of country nearly two miles in width. Large quantities of gypsum are also found in places in the clay. On Burnet creek, one mile east of Wills Point, gypsum crystals five to six inches long are frequently found. One of the most constant characteristics of the clay is the presence in it of soft small white calcareous concretions one-tenth of an inch to two inches in diameter, which often have the cauliflower-like form of some of the geyserite of the Yellowstone Geyser basins. They are found very plentifully, and often collect in large quantities in creek beds.

Interstratified with the clays, and inclosed between the upper brown clay and the lower dark blue division, there occurs a series of beds of white fossiliferous limestone and brown and dark bluish-gray sands. These beds show a section of:

1. White limestone containing numerous casts of shells..... 8 feet.
2. Brown sand ..... 2 feet.
3. Limestone similar to No. 1, but containing a greater number of bivalve shells..... 10 feet.
4. Dark bluish gray sand ..... 30 feet.

These limestones and associated sands first appear upon the crest of the hill about half a mile northwest of the village of Elmo, where the upper limestone forms the surface of the hill for about 100 yards. Nearer the

village the limestones appear in a well digging, and are overlaid by the yellowish brown sand everywhere forming the surface deposit of this region. On going eastward from Elmo the limestones again appear in a tank at Cobb's switch; and about a mile furthur east, on Rocky Cedar creek, they attain their maximum thickness of twenty feet.

At Prairie Grove postoffice, about two miles north of the railway crossing over Rocky Cedar, the limestones also appear in most of the streams in the region, and from their thickness appear to extend much further north.

A general section of the beds within the region around Wills Point gives the following:

1.	Yellowish brown sand containing calcareous bowlders of sandstone, limestone with thin veins or seams, occasionally nodules of crystalline calcite, and containing occasional fossil remains...	30 feet.
2.	Yellow laminated clay with thin partings of yellow sand and containing occasional bowlders of siliceous limestone.....	90 feet.
3.	Massive bedded clay, showing no signs of lamination, containing numerous bowlders similar to those of No. 1.....	30 feet.
4.	White limestone containing great quantities of fossil casts, chiefly *Turritella*, *Cardita planicosta*, *Ostrea* (?) and other bivalve shells.....	8 feet.
5.	Brown sand.....	2 feet.
6.	Limestone similar to No. 4.....	10 feet.
7.	Bluish gray sand.....	30 feet.
8.	Dark blue laminated and much joined clays with thin sandy partings, containing occasional small bivalve shells chiefly, and having a thin pavement of siliceous nodules near its upper surface	62 feet.
9.	Ponderosa marls.....	.....
		262 feet.

The dip of these beds, where traversed by this section, ranges from less than one to nearly five degrees, in a southeast direction.

The greater portion of the area occupied by these deposits consists of prairie with small patches of timber lands interspersed. The timber is mostly blackjack and postoak, with a few black ash and sycamore trees along the creeks.

From the contact of the laminated blue clays with the Ponderosa marls, three miles west of Elmo, to the point of the disappearance of the yellow clay, three miles east of Wills Point, the width area embraced by the Basal clays of the Tertiary deposits in this portion of the State is

fifteen miles, and the complete section of these clays and sands shows them to have a total thickness of at least two hundred and sixty-two feet.

THE BRAZOS RIVER SECTION.—The representatives of these beds on the Brazos are seen in the bluffs of the river extending from the northeast corner of Milam county down the river to within two miles of Pond creek, a distance of about seven miles. These clays here overlie the Blue Marls, which are extensively developed between this point and Waco. They differ somewhat in lithological character from the clays at Wills Point, and are at many places highly fossiliferous. The first bluff showing them, coming down the river, is in the corner of Milam county. It is about a third of a mile long and forty feet high. The lower part of it is composed of very dark, almost black, clays, containing fragments of shells, and running into a lighter yellowish and greenish clay towards the top. This upper part contains highly calcareous indurated strata, showing a nodular structure and containing many fossils. The lower part of the bluff is also calcareous, but not as much so as the upper part. Dip, three degrees southeast. At a point two miles above Pond creek is another bluff of interbedded dark gray clays and white and gray sands, containing many flat calcareous concretions, weathering in concentric layers and one to ten feet in diameter. They are dark gray inside and brown on the outside. They are in the sand seams, and are probably simply part of the inclosing stratum indurated by the large amount of calcareous matter that they contain. In a thin bed of clay, four inches thick, in this bluff are found many shells of an oyster. The dip of the bluff is very gentle to the southeast. It becomes much more sandy towards the top than at the base, and doubtless represents the transition bed from the Basal Clays to the great overlying series of sandy strata (Timber Belt beds).

THE COLORADO SECTION.—The Basal Clay bed in Bastrop county is seen to the west of Elgin, and between that point and Manor, in Travis county. It forms the same character of country as in the northern part of the State, and finally disappears to the east under the overlying sands. On the Colorado river it is seen cropping out at a point sixteen miles by river below Austin, and one mile below the mouth of Onion creek, in a bluff some forty feet high and a mile long. Also at Webberville, on the line between Travis and Bastrop counties, where it is seen in a low bluff just

above the water's edge. This is a much darker and more massive clay than that seen in most other outcrops. In the bluff sixteen miles below Austin are found a few fragments of fossils, but they are all so broken as to make their determination very doubtful.

The extension of the Basal Clays west of the Colorado has not been studied. It may be that the beds observed at Webb Bluff on the Rio Grande belong here, but their reference to these beds must await the determination of the fossils collected from them. No lignite beds have as yet been observed in these clays.

THE TIMBER BELT DIVISION.

The Basal Clays everywhere, from the northern part of the State to the Colorado river, blend upwards into the sandy Timber Belt beds. These form a large part of the Tertiary formation in Texas, and underlie the great timber region of the eastern part of the State. They are composed entirely of siliceous and glauconitic sands, with white, brown, and black clays. The clays, however, are greatly in the minority, and the siliceous sands compose by far the larger part of the whole series. Lignite beds are of very frequent occurrence, varying from a few inches to ten and twelve feet thick; and the sands and clays are often impregnated with vegetal matter to such an extent that numerous traces of petroleum, asphalt, and natural gas have been found in the East Texas region, sometimes in quantities of considerable economic importance. Many of the black and brown clays and sands owe their coloring matter to this ingredient of vegetable material, and burn white or buff color when exposed to heat. These beds occupy an area over 125 miles wide in the northeast part of the State, but thin down to less than 40 miles on the Colorado. This greater development of the Tertiary strata to the northeast is probably due to a greater deposition in the vicinity of the embayment which existed in the lower Mississippi at the time they were laid down, or to the overlapping of deposits of later age toward the southwest.

The sands are generally much cross-bedded, gray to buff in color, and contain black specks, which are often glauconite. This latter mineral is a common constituent in many of the beds, and there are found all gradations, from a pure siliceous sand to a pure greensand bed, such as are well developed in the iron ore regions of Anderson, Cherokee, Rusk and other counties. All the sand beds are more or less impregnated with carbonate

of lime, and often it is in such quantities as to form beds of calcareous sandstone, where it acts as a cement, and forms a soft, friable rock. Sometimes even beds of limestone are found, and calcareous nodules and concretions are of very frequent occurrence throughout the whole of the Timber Belt beds. One of the most characteristic features of the region depends on this presence of carbonate of lime in the sandy beds. It is the occurrence of great masses of sand, varying from one to ten feet and more in diameter, and cemented into a hard rock by the calcareous matter. These rocks vary much in shape and hardness. Sometimes they have a concretionary shape and weather in concentric layers; at others they show the horizontal stratification of the beds in which they occur, and gradually blend into the soft enclosing sand.

Many of the sands are also intimately mixed with a fine impalpable white clay, which renders the beds soft and highly plastic when wet, but when dry it forms a hard, solid mass, often occurring as a friable sandstone. When such beds are exposed to erosion by creeks and in gullies they break up into lumps, which become rolled and rounded, and form putty-like pebbles. The sand beds are generally also variable in composition. They blend by insensible gradations, both vertically and laterally, into clay or sandy clay beds, so that minute correlations, even in beds very close to each other, are difficult to make. This extreme variability in composition is simply one of the many proofs of a near shore deposit. The sand beds often contain considerable quantities of dark brown or gray mica. The clay beds of this division vary from a pure white highly plastic clay to a dark brown, or even black, material containing large quantities of lignitic matter. They are generally laminated, or finely stratified, and frequently occur interbedded with thin seams of sand, the latter often in lenticular streaks, while the clay is generally continuous. The seams of clay vary from one-twentieth to one-eighth inch in thickness, and the sandy seams are but very little thicker. The whole formation shows a peculiar undulating section, the undulations being due to the thinning and thickening of the sandy seams and not to lateral pressure.

The brown coal beds of this series are composed both of brown and black varieties. Silicified wood is of very frequent occurrence, sometimes simply in small fragments, and at others as large trunks of trees. It

is generally dark brown or black inside, and weathers gray or buff color on the outside. Sometimes it occurs partly lignitized and partly silicified. It frequently shows shrinkage cracks which are filled with quartz or chalcedony, and often lined with quartz crystals.

Carbonate of iron, in the form of clay ironstone, is of very frequent occurrence throughout the Timber Belt beds. It rarely occurs in a continuous seam, but is found in lenticular masses and nodules, often occupying the same plane of stratification for considerable distances. Sometimes these masses coalesce into a bed continuous for a few hundred yards. They are rarely over three or four inches in thickness, and are generally rusty from oxidation. They are probably the source of some of the brown hematite iron ores in the counties north of the Sabine river. Iron pyrites is an almost inseparable accompaniment of the beds.

The Timber Belt division has been provisionally separated into the Lignitic and Marine beds.

LIGNITIC BEDS.

East Texas Section.—Immediately succeeding the Basal Clays, and in close contact with them, there lies an extensive series of sands, clays, and brown coals, having an aggregate thickness of over 900 feet.

The western outcrop of these deposits occurs about three miles east of Wills Point, and the deposits themselves extend eastward beyond the Louisiana line. Their northward extension has not yet been determined, but members of the series occur near Springdale, Douglasville and Hughes Springs, in Cass county, Daingerfield in Morris county, and at Alba, in Wood county. In their southern extension they have been traced through Cass, Marion and Harrison, to the Sabine river. Similar beds also occur in Gregg county, south of Longview, in Upshur county, near Wilkins' mill, and in Smith county, near Tyler.

The sands are variously colored, being white, yellow, brown, red, gray, blue, and black, the colors often shading into one another, and with the exception of the dark blue or black, and occasionally white beds, present no uniformity of coloration for any distance. In structure they are laminated or thinly stratified, massive, cross-bedded, and frequently interlaminated with clay. In estimating their dip or thickness

no reliance can be placed upon their structure, as the beds occur in all positions and dip at all angles.

The clays occur interstratified and interlaminated with the sands, and in such positions are mostly laminated. Massive and stratified beds also occur in many portions of the area, sometimes nearly free from sand, but the greatest portion are sandy or micaceous clays. In color they are generally dark blue, gray, and black. Occasionally deposits of red and yellow clay occur, and frequently thin beds of white are found among the upper members of the series.

The uppermost member of the deposits belonging to this group appears to be a series of laminated or thinly stratified white and red sands and sandy clays, frequently merging into one another and forming a mottled sandy clay or clayey sand. The laminæ generally do not exceed one-fourth to half inch, but the white sandy clay frequently expands to six or more feet. This series is best developed in the neighborhood of Queen City, Cass county, where it has a known thickness of sixty-five feet, for which reason it has been called the Queen City beds. In Marion county, near Jefferson, and in Harrison county the beds appear at various places immediately underlying a yellowish-brown sandstone, or altered glauconite, containing occasional casts of fossils, chiefly of the *Cardita planicosta* type. They occur also near Tyler, in Smith county, and as far south as to within two miles of Troupe. Towards the north they occur at Gladewater, in Gregg county, and from Wilkins' mill, in Upshur county, westward to within a short distance of the Big Sandy.

The lowermost beds of these deposits are not as yet exactly known, but from the records of the several deep wells bored within the area, appear to be dark blue or brown clays. The yellow and brown sands found near the contact with the Basal Clays west of Edgewood do not represent the beds in absolute contact with the underlying Basal Clays, but are probably an overlap of some of the higher deposits belonging to this group. This condition is extremely probable, as towards the southwestern portion of Van Zandt county, and only a distance of two miles or so from the place where the Basal Clays are last seen, lignitic deposits occur in association with blue clay.

Between the Queen City beds and the lowermost deposits of that group there lies a series of black, blue and gray micaceous sands, blue, brown

and gray clays, with thin strata of sandstones and limestones, and also containing many small seams and several heavy deposits of lignites, which unfortunately are not visible, or only partially so, at any of the places yet visited.

Towards their southern side the beds belonging to this division present the initial flexing so largely developed throughout the immediately overlying marine or glauconitic beds. These undulations occur at many places south of the Sabine river, in Smith county, beginning a few miles south of Lindale, and extending as far south as Bullard, where the beds pass under the glauconitic sands of the Mount Selman series. From whatever cause this flexing may have arisen, it is evident that the same action involved the structure of these as well as the succeeding beds, although they are widely separated in composition and the conditions under which they were deposited. A striking resemblance between the flexures of the two sets of beds, leading to the conclusion that this bending took place after the upper deposits had been laid down, is their general coincidence with each other and their uniform tendency to a northeast and southwest course, or a course approximately parallel to the old Cretaceous shore line.

These deposits so far have yielded no fossils beyond a few broken plant remains found in the stratified bluish sandy clay north of Grand Saline.

The structure and position of these beds can best be seen in the following well section:

SECTION OF WELL AT MINEOLA.

		Thickness.		Depth.	
1.	Top soil	1	foot.	1	foot.
2.	Red clay	11	feet.	12	feet.
3.	Gray or white sand with water	8	feet.	20	feet.
4.	Brownish black clay	5	feet.	25	feet.
5.	Brown clay	10	feet.	35	feet.
6.	Blue clay	15	feet.	50	feet.
7.	Brown clay, sand and mica	16	feet.	66	feet.
8.	Lignite sand and iron pyrites	4	feet.	70	feet.
9.	Sandstone with water	1	foot.	71	feet.
10.	Blue clay or mud	4	feet.	75	feet.
11.	Gray sandstone with water	5	feet.	80	feet.
12.	Blue clay	20	feet.	100	feet.

		Thickness.		Depth.	
13.	Potter's clay	10	feet.	110	feet.
14.	Sandstone with water	5	feet.	115	feet.
15.	Gray or blue clay	½	foot.	115½	feet.
16.	Sandstone with water	9½	feet.	125	feet.

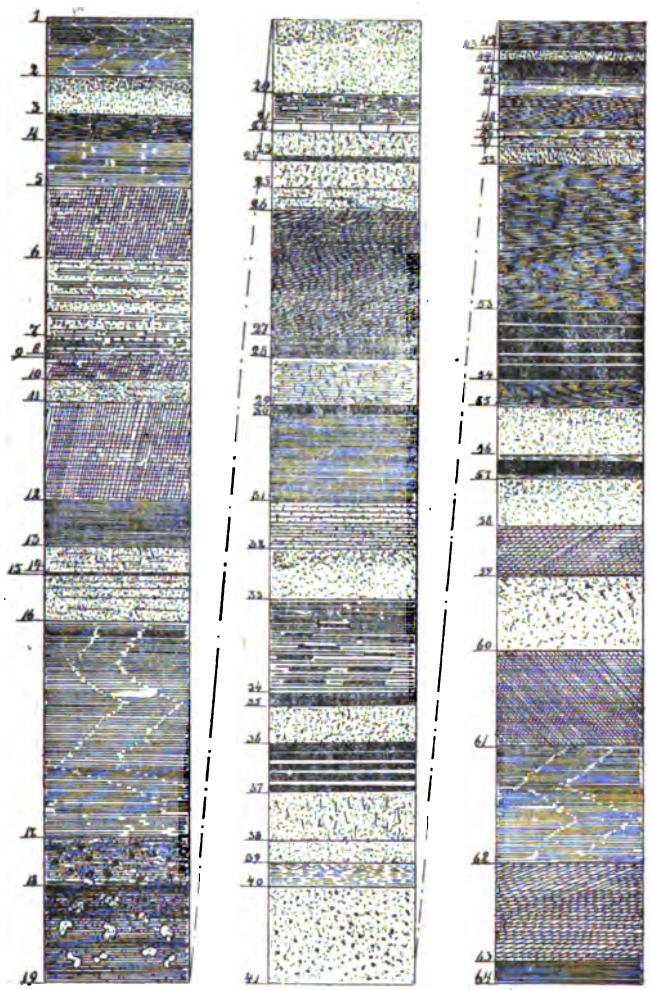


Fig. 8.

Well at Mineola. Scale 1 inch=40 feet.

17.	Bluish gray clay and pyrites	45	feet.	170	feet.
18.	Bluish gray clay with some sand	10	feet.	180	feet.
19.	Blue clay with limestone bowlders	20	feet.	200	feet.
20.	Gray sand	15	feet.	215	feet.

		Thickness.		Depth.	
21.	Black clay with limestone, pyrites, etc.	6	feet.	221	feet.
22.	Dark limestone	2	feet.	223	feet.
23.	Gray sand and mica	5	feet.	228	feet.
24.	Black and blue clay, mica and pyrites	1	foot.	229	feet.
25.	Gray sand, mica, brown clay and water	6	feet.	235	feet.
26.	Sandstone with water	4	feet.	239	feet.
27.	Brown black clay	26	feet.	265	feet.
28.	White clay	5	feet.	270	feet.
29.	White or gray clay, sand, mica and pyrites with water	10	feet.	280	feet.
30.	Lignite*	1	foot.	281	feet.
31.	White clay with thin strata of sand with water	19	feet.	300	feet.
32.	Brown clay and white sand	10	feet.	310	feet.
33.	White sand with water	10	feet.	320	feet.
34.	Brown clay and lignite	20	feet.	340	feet.
35.	Brown joint clay	2	feet.	342	feet.
36.	Gray sand	8	feet.	350	feet.
37.	Gray sand and lignite	10	feet.	360	feet.
38.	Gray sand and pyrites	10	feet.	370	feet.
39.	White sand	5	feet.	375	feet.
40.	Grayish white sand and black mud	5	feet.	380	feet.
41.	Coarse white sand with grains of lignite and water	20	feet.	400	feet.
42.	Brown clay	5	feet.	405	feet.
43.	Lignite	1	foot.	406	feet.
44.	White sand, very coarse, with water	2	feet.	408	feet.
45.	Lignite	3	feet.	411	feet.
46.	Gray clay	2	feet.	413	feet.
47.	Grayish white clay	3	feet.	416	feet.
48.	Brown clay	5	feet.	421	feet.
49.	Dark brown clay	1	foot.	422	feet.
50.	Black mud	2	feet.	424	feet.
51.	Black mud, sand and lignite	2	feet.	426	feet.
52.	Iron pyrites and black mud	4	feet.	430	feet.
53.	Black brown clay and pyrites	30	feet.	460	feet.
54.	Lignite	15	feet.	475	feet.
55.	Black brown clay	5	feet.	480	feet.
56.	Gray sand with water	10	feet.	490	feet.
57.	Lignite	5	feet.	495	feet.
58.	White sand with water	10	feet.	505	feet.
59.	Dark brown joint clay	10	feet.	515	feet.
60.	Gray sand, mica and water	15	feet.	530	feet.
61.	Dark brown clay	20	feet.	550	feet.

*"Lignite" in this section may mean either brown coal or lignite. We had no specimens of it.

		Thickness.		Depth.	
62.	Grayish blue clay	25	feet.	575	feet.
63.	Dark brown clay	20	feet.	595	feet.
64.	Joint clay and sand at bottom of boring	5	feet.	600	feet.

THE BRAZOS RIVER SECTION.—About a mile and a half below Pond creek, in Milam county, is seen an outcrop of Tertiary sand, containing black specks and rendered plastic by a white clay. It is capped by semi-indurated Quaternary gravel and sand, and contains large nodules which give a strong reaction for carbonate of lime, and which are simply hardened masses of the enveloping sand. They are one to eight feet in diameter, hard, kidney-shaped, flat or nodular, and project out of the compact sandy bluff in a most characteristic manner. Loose fragments of silicified wood, which have also doubtless been derived from the same bed, lie among the many nodules that have been eroded out. So many of these rocky masses have been loosened from the sand and piled up in the bed of the river that they have obstructed its course, and have formed rapids. Many of these rocks are round or oval, and are locally known as "kettle bottoms." Such strata as these are seen down the river for a mile and a half from this point, where they dip under a series of gray clays containing beds of brown coal, varying from one to five feet thick and associated with ferruginous sand. The clays contain large masses of silicified wood, which is sometimes seen in places in the bed, but more often has been weathered out and lies in the bed of the stream. Occasionally nodules of clay ironstone, generally in a semi-oxidized condition, are found. Such strata are exposed for about a mile, when the gray sands with calcareous concretions and indurations again appear. This deposit contains considerable quantities of iron pyrites, and the indurations are often cut by veins of crystalline calcite. A short distance below here is Calvert Bluff, Robertson county, where brown coal occurs in large quantities and has been worked intermittently for many years.

The clay beds at this locality contain large clay ironstone concretions, which enclose many leaf impressions. From here to where the International and Great Northern Railroad crosses the river we see sand beds with calcareous indurations, such as have been described at Rocky Rapids. At this point is a bluff showing sixteen feet of Tertiary strata, capped by over fifteen feet of a highly calcareous light green and yellow Quater-

nary clay containing many small white concretions. The base of the Tertiary part of this bluff is composed of black clay from the water edge up to ten feet above it, and is overlaid by six feet of non-fossiliferous greensand marl. Quaternary deposits lie unconformably on the Tertiary strata. For twelve miles below this point is seen a series of interbedded and interlaminated clays and sands, with occasional beds of brown coal, and some few small gray calcareous concretions. Frequently small fragments of lignite are seen in the sand beds, showing that the swifter waters, which changed the character of the bed from clay to sand, were also responsible for the destruction of lignite beds, the fragments of which were deposited with the sand.

Colorado River Section.—Five miles by river below the outcrops of Basal Clays in the neighborhood of Webberville, is seen a low bluff, rising some four feet above the water and a quarter of a mile long, composed of glauconitic marl with many Eocene fossils. This represents the lowest fossiliferous bed of the Timber Belt series in this locality. From a point two miles below the Bastrop county line to the town of Bastrop is about twenty miles by river. In the distance are seen numerous outcrops of gray sands, cross-bedded, and containing black specks, which are often glauconite, as well as large concretionary and indurated masses, like those already described on the Brazos at Rocky Rapids. As at Rocky Rapids, they doubtless owe their existence to the presence of argillaceous and calcareous matter, which has acted as a cement. Here, however, on the Colorado they are much fewer and smaller (one to four feet in diameter) than on the Brazos, and form a much less important part in the topography of the river channel. The sand beds are frequently interstratified with beds of gray clay. Many beds of brown coal, one to five feet thick, are found cropping out in the bluffs, and thin seams and lenticular masses of carbonate of iron are frequently seen throughout the formation. This latter is generally partly decomposed and exposes a rusty surface. Frequently it shows shrinkage cracks, proving its once gelatinous condition. The dip of these sands and clays is to the east and southeast at an angle of from 0 to 5 degrees. The bluffs are usually capped by from ten to thirty feet of Quaternary gravel and sand.

From Bastrop down the river for eight miles a series of interbedded and interlaminated gray, brown, and chocolate clays and sands is seen in many bluffs. The seams of clay are often not over one-eighth inch in

thickness, and yet they preserve a very remarkable continuity; the interlaminated sand occurs as a series of connected lenses, and gives the underlying and overlying clay laminæ characteristic undulating appearance.

Brown coal beds are very plentiful throughout the series, and vary from one to eight feet thick. They are generally conformable in a general way with the overlying and underlying strata, but sometimes they are unconformable.

Twelve miles below Bastrop is "Red Bluff." This is about a hundred feet high and capped with a Quaternary conglomerate from three to twenty feet thick, and composed of pebbles of flint, chert, quartz, feldspar, and jasper, one-sixteenth to six inches in diameter, and cemented in a highly ferruginous sand. It frequently contains patches of red and mottled sand, and is of a bright red color. The foot of the bluff is covered by immense blocks that have fallen from this bed. Underneath the conglomerate is a bed of white Tertiary sand, in places thirty feet thick. It is frequently rusted on the surface from the ferruginous solutions running down from the overlying conglomerate. Below the sand are fifty feet of interlaminated seams of chocolate clay, sandy clay, and gray sand. At the base of the bluff the sand bed contains large black indurated masses of sandstone, as at Rocky Rapids, on the Brazos. The whole bluff has a red appearance, the effect of which is greatly enhanced by the patches of unstained white sand occasionally seen. Half a mile below this point is seen a similar though smaller bluff of the same strata. For two and a half miles below this are seen scattered outcrops of gray sands and plastic clays, containing brown coal deposits.

Rio Grande Section.—Three miles below the north line of Webb county we obtained the following section:

Gravel	
Sandstone white and glistening, with mica and some little iron; calcareous sandstones; clay with "cannon ball" concretions, and small seam of grahamite	30 feet.
Greensand marl with many Tertiary fossils: nodules of carbonate of lime; specks of glauconite	7 to 8 feet.
Stiff, plastic, dark greenish or blue clay jointed (*Cretaceous*)	10 feet.

A quarter of a mile below is a bluff fifty feet high of indurated sandy clay, containing mica and ferruginous scales between the strata. Dip 1 degree south. One and a half miles below are seen similar deposits, but with no fossils, and containing numerous gray calcareous concretions, with veins of brown crystalline calcite. Two miles beyond this, on the

Mexican side, is a bluff a quarter of a mile long and seventy-five feet high, of interlaminated gray sands and chocolate clays, with sulphur and gypsum in places, and occasional ferruginous spots. Hard gray clay ironstones with leaf impressions are also found. The sand beds are from one to five feet thick, and the clay is in thin laminæ. Dip undulating from 1 to 5 degrees southeast. The mica and black specks in the sand, the laminæ of chocolate clay, the presence of sulphur and gypsum crystals, all show a strong resemblance to the Tertiary of East Texas. From here to the Hardin Ferry, and thence to the mouth of the Cavezeras river,are seen similar strata, frequently causing rapids where they cross the Rio Grande. In one place the indurated bluffs encroach on the river until it narrows down to thirty yards. Here the waters have cut a deep channel and rush through at a great velocity. Frequently interbedded glossy brown ferruginous layers one or two inches thick, are found in the sandstone. Three miles below "the Hardin" is a bluff sixty feet high composed of friable sandstones, the harder and softer layers blending into each other and occasionally showing ferruginous patches. Dip 1 degree south. For nineteen miles below this point we pass over identically similar strata, frequently containing calcareous concretions one to three inches in diameter. These contain seams of crystalline calcite, and are of a gray color, weathering brown or red in concentric layers.

Similar strata are seen from here to the San Tomas coal mines. These are situated on the Texas side of the river and at the mouth of San Tomas creek, about twenty-five miles by river above Laredo.

For three miles below this are seen indurated greenish clays with leaf impressions, broken stems, and specks of lignite. Occasionally seams of chocolate clay and calcareous nodules are found. As usual, the bluffs are capped with pebbles or sand, and dip two degrees southeast. Fifteen miles above Laredo is a bluff reaching a maximum height of forty feet, and about a mile long. It is composed of interbedded coarse sand with calcareous nodules, and sandy clay with gypsum and sulphur. The sand grains are red, yellow, white, and gray, and the whole bluff has a greenish appearance, spotted in places by ferruginous matter. Many similar outcrops are seen for seven miles below, and as the dip is often horizontal, or nearly so, the exposures show simply different parts of the same bed. Eight miles above Laredo is a bluff about eighty feet high and a half mile long, composed of semi-indurated buff sands with an undulating

dip. Similar exposures are seen down the river to Laredo, and in fact that town is built partly on the same beds, which are here succeeded by those of the next division of the Eocene.

MARINE BEDS.

EAST TEXAS SECTION.—The succeeding beds in the ascending scale are a group of marine deposits consisting of a series of sands, greensands and clays, having a total thickness of approximately six hundred and fifty feet.

Their areal extent in this region embraces a ridge of land, approximately forty miles in width and having an elevation of from three hundred and fifty to seven hundred feet above tide, extending across the counties of Harrison, Gregg, Rusk, Smith, Cherokee and Houston. They occupy the greater portions of Cherokee and Anderson counties, the whole of the northern half of Houston county, and a great extent of Sabine, Nacogdcohes and San Augustine, as well as portions of Smith and Henderson counties. Across the Trinity they extend westward, and in Harrison county, to the northward they narrow to a point, and become more or less broken into isolated hills. Small outliers of the same age are also found at Hughes' Springs and at Atlanta and in the northern part of Cass county.

The outlines of these beds have not yet been traced to any extent. They are known to overlie the red and white sands and sandy clays of the Queen City beds in Harrison county, three miles north of Marshall, where they come in direct contact. To the west of Marshall they are again seen overlying the Queen City beds. On the south side of the Sabine river, the brown ferruginous sandstones belonging to the basal division rise thirty feet above the level of the river. Westward, in Smith county, near Bullard, six miles north of Mount Selman, the base of the series is found in wells at a depth of twenty-four feet, resting upon a black lignitic clay. In Henderson county they occur only in the southeastern portion as iron capped hills. Toward the south, in Houston county, they dip under a series of thinly laminated blue clay and sand containing crystals of selenite; and near Alto, in Cherokee county, the upper beds are overlaid unconformably by a series of black clays and sands containing crystals of gypsum.

The Marine beds may be divided into two groups—the basal, from its greatest development in Cherokee county, may be called tentatively the

"Mount Selman" beds, while the uppermost, from its typical development in Houston county, may be denominated the "Cook's Mountain" beds.

THE MOUNT SELMAN BEDS.

The beds of the Mount Selman series rise abruptly on the northward to a height of seven hundred feet above sea level, and consist of a series of brown sands, blue clays, greensands, altered greensands, glauconitic sandstone and laminated iron ore, and are more or less fossiliferous throughout.

General section from Jacksonville to Bullard, across the Mount Selman beds:

1.	Gray sand	10 feet.
2.	Brown sand, ferruginous pebbles and iron ore	15 feet.
3.	Mottled sand	10 feet.
4.	Brownish yellow sand	4 feet.
5.	Brown and yellow sandstone	10 feet.
6.	Alternate strata of iron ore and brown sand, the ore in generally laminated deposits of two to ten inches, and sand from one to two feet	8 feet.
7.	Dark green sand containing casts of small bivalve shells	5 feet.
8.	White clayey sand	1 foot.
9.	Dark green nearly black sand, containing thin seams of ferruginous materials near top, and also containing small fish teeth and *Cardita planicosta*	12 feet.
10.	Brown sand	10 feet.
11.	White sand	10 feet.
12.	Alternate strata of brown sand and laminated iron ore, ore generally wavy and not more than two to six inches, and sand one to two feet	20 feet.
13.	Pale blue and brown clay, mottled in places and laminated in others	15 feet.
14.	Alternate strata of altered glauconitic brown sand and iron ore, the ore generally irregularly deposited, laminated and siliceous, and not exceeding six inches to one foot, the sand from six inches to two feet	55 feet.
15.	Brown sand, forming the surface near Bullard, but passing under No. 12 at the base of the hill, altered greensand, changing to yellow a few feet under ground	40 feet.
16.	Dark green sand, containing fossil shells and a few shark teeth	24 feet.
17.	Lignite or "black dirt," having the appearance of drift, containpieces of wood, leaves, etc	2 feet.
18.	Dark lignitic clay, jointed in places, and having the joints filled with glossy lignitic material and sand, and said to contain small white shells near the bottom	5 feet.
19.	Brown clay at bottom of well near Bullard, dug into	2 feet.

The minor folds noticed in the beds between Mineola and Tyler are greatly increased in force in the Mount Selman beds, and even this

mountain, which may be looked upon as being among the highest, if not the highest point in this portion of the country, shows its structure to be that of an elevated synclinal trough. Minor undulations also occur throughout the whole series of the deposits to the southward as far as New Birmingham, and probably further to the southeast than is at present known.

The prevalent idea that the changes of dip found in the overlying beds are due to the erosion of the lower sand deposits, through the action of springs and other underground waters, will have to be abandoned. It is undoubtedly true that many of the changes found locally in the neighborhood of the streams are due to this kind of erosion, but some other cause must be found for such an extensive series of undulations as occur in this region, involving as it does two so widely separated sets of deposits as these and the underlying lignite beds. Our present knowledge of the life history of these deposits is extremely meagre. The only fossils so far found consist of a few broken undetermined shells of the *Cardita* type, a few casts of a small bivalve, and several small shark teeth.

COOK'S MOUNTAIN BEDS.

The chief characteristics of the upper group of the Marine beds are in many respects lithologically the same as those of the Mount Selman beds. They comprise an extensive series of greensands, and greensand marls, altered greensand containing thin strata of carbonate of iron, indurated altered fossiliferous greensand, green fossiliferous clays, glauconitic sandstones and clays, stratified black and gray sandy clays, brown fossiliferous sands, and black or yellow clays with limy concretions, with occasional local deposits of black sand with gypsum crystals. The prevailing deposits, however, are the greensands in their several characters. A striking distinction between this series and the underlying Mount Selman is the extensive fauna found in the Cook's Mountain beds.

The general section here given represents the beds of this group from Independence postoffice, in Cherokee county, to Alto, a distance of twenty-five miles.

SECTION—INDEPENDENCE TO DIAL.

1.	Cross-bedded sand with nodules of white clay.....	5 feet.
2.	Altered greensand containing white nodules, thin streaks of iron ore and casts of fossils.....	80 feet.

3.	Mottled brown and white sand	2 feet.
4.	Thinly laminated blue sand	6 feet.
5.	Thinly stratified or laminated red and white sand and white clay	6 feet.

SECTION—RUSK PENITENTIARY HILL.

1.	Gray sand	20 feet.
2.	Interstratified laminated ferruginous material, iron ore and altered greensand	40 feet.
3.	Laminated or thinly stratified red and whitish blue sand and sandy clay	20 feet.
4.	Mottled red and blue sandy clay, probably belonging to and forming the lower part of No. 3	25 feet.
5.	Red sand and ferruginous gravel	5 feet.
6.	Brownish stratified sand, mottled in places	60 feet.
7.	Grayish blue stratified sand in creek	3 feet.

NEW BIRMINGHAM SECTION.

1.	Clay	10 feet.
2.	Micaceous sandstone containing iron	3 feet.
3.	Sandstone	8 in.
4.	Micaceous sand	1 foot.
5.	Altered glauconite containing casts of fossils	6 feet.
6.	Quicksand	1 foot.
7.	Altered glauconite, with casts of fossils and thin seam of sandstone near centre	21 feet.

ALTO REGION.

1.	Gray sand	5 to 20 feet.
2.	Ferruginous sandstone	1 foot.
3.	Iron pyrites and lignite	1½ feet.
4.	Laminated iron ore and brown sand (altered greensand)	10 to 15 feet.
5.	Fossiliferous altered brown glauconitic sand, containing *Anomia ephippioides*, *Ostrea sellæformis*, *Cardita planicosta* and other fossils, and streaks and nodules of calcite	6 feet.
6.	*Yellowish brown and grayish brown indurated glauconitic sand containing *Scutella caput-linensis*, *Ostrea sellæformis*, and other fossils	20 feet.
7.	Greensand containing casts of fossils	6 feet.
8.	Brown sandstone, altered glauconite with casts of fossils	30 feet.
9.	Greensand with gasteropods and fish teeth	8 feet.

These beds present in some slight degree the same undulating structure as is seen in the Mount Selman beds. This, however, is only seen near the base of the series, and where they come in direct contact with the beds of that division. As they ascend the scale the flexing ceases altogether, or is so slight as not to be appreciable. Toward the southern border these deposits assume a general uniform southeast dip of nearly

*This bed forms a well defined horizon from the Louisiana line westward to and beyond the Trinity river.

sixteen feet to the mile. The southern border, so far as has been traced, breaks off somewhat abruptly, and is strongly indented by several great bay-like openings, and probably more than one long, narrow, river-like channel, through and among which the succeeding deposits have been formed in an unconformable manner.

The southern boundary can be easily traced from its entrance into the State in Sabine county, through San Augustine, Nacogdoches, Cherokee and Houston, as far west as the Trinity river, and probably much further, by a heavy bed of grayish brown, changing to a yellowish brown indurated sand, characterized wherever found by the presence of the fossils, *Scutella caput-linensis*, and *Ostrea divaricata*. Other fossils occur in this bed, but so far as yet known these appear to belong almost exclusively to it. It is usually about twenty feet thick, and the *Scutella caput-linensis* have not as yet been found in any of the others. The bed immediately overlying this is a brown altered glauconitic sand, with calcitic streaks and nodules containing *Anomia ephippioides* in great quantities, *Ostrea sellæformis*, *Cardita planicosta* and other fossils. This bed occurs at the two places, Alto and Cook's mountain, and at many intermediate points. It does not, however, exceed a general average thickness of ten feet, being six at Alto and ten in Houston county.

Brazos River Section.—In the northern corner of Burleson county, and two and a half miles below where the north boundary of the county crosses the Brazos, is seen the first fossil-bearing stratum that has been met along the river below the Basal clays. Here is found a bluff, about thirty-five feet high, giving the following section:

BURLESON SHELL BLUFF.

1.	Fossiliferous greensand marl	10 to 20 feet.
2.	Interbedded and interlaminated dark brown and black clays and sands	8 feet.
3.	Brown coal	2 feet.
4.	Gray sand	3 feet.
5.	Interbedded and interlaminated dark brown and black clays and sands to water edge	4 feet.

Dip of the above section, 3 degrees southeast.

The greensand marl is rusty and indurated in places, and in others retains its green color. It contains a few gray calcareous concretions, one to three inches in diameter, and is often literally made up of fossils. One mile below this point the same bed is seen dipping under the water level. For six miles below this point is seen a series of interbedded and

interlaminated sands and clays, often much colored by lignitic matter, and containing a heavy bed of brown coal. The sands are much cross-bedded, and contain considerable quantities of iron pyrites. The dip is irregular and undulating, frequently tending toward the north. Six miles below Burleson Shell Bluff we come to Moseley's Ferry (San Antonio Ferry), where we again find glauconitic deposits rich in fossils. These are twelve feet thick and underlaid near the water edge by a chocolate brown clay containing gray calcareous concretions. The green-sand marl is rusty and indurated in places, soft and green in others. Fossils are very numerous, and many species resemble those of White Marl Bluff, on the Colorado.

Colorado River Section.—The first exposure of these beds on the Colorado is at Bombshell Bluff, which is seventeen miles by river below Bastrop, and is in the southern part of Bastrop county. It consists of thin interstratified layers of glauconitic marl, black clay, and dark siliceous sand with glauconite specks, and is the first fossil-bearing stratum seen after leaving Travis county. Interstratified with these deposits is a hard-indurated ledge of calcareous rock, made up largely of glauconite and weathering white. Dark gray round and oblong calcareous concretions are found throughout the clay and sand. The bluff is about ten feet high, and about half way up it is a bed three to eight inches thick, very much rusted and with streaks of hard-pan. This seam is one which contains most of the fossils, and in some places is almost entirely made up of them. They are entirely of Claiborne age. The sands are cross-bedded and the whole bluff is heavily charged with iron pyrites. Numerous specks of lignite are found, even with the shell-bearing strata, proving beyond a doubt the littoral character of the deposit. The dip is about horizontal. For four miles below this are seen similar ledges of the same strata, all preserving an almost horizontal dip. Frequently gypsum crystals are found in the clays. Four miles below the beginning of this fossiliferous area we come to what is locally known as the Devil's Eye, an eddy at a low ledge of a similar formation to those just described. The strata here belong to the same series as those just passed. The fossil-bearing bed is six to twelve inches thick, is semi-indurated, and composed almost entirely of glauconite and shells. Specks of lignitic matter are found throughout the associated chocolate clays, and also, occasionally small quantities of rusty clay ironstone are seen. Dip, horizontal. Alum

Creek Bluff is at the mouth of Alum creek and a short distance above Smithville. It is forty feet high, and shows the same charater of strata and the same shell bed as is seen at Devil's Eye. It is underlaid by twenty feet of much cross-bedded sands, and dips 3 degrees to the southeast. Between here and Smithville is seen a series of interlaminated sands and clays, barren of fossils and dipping 5 degrees southeast. At Smithville, in the eastern part of Bastrop county, are found interbedded deposits of glauconitic marls and chocolate clays in a bluff thirty feet high and capped with Quaternary gravel. The glauconitic marl is hardened and rusty in places, and in others is soft, green, and entirely unaltered. It is highly fossiliferous and contains numerous Claiborne species.* Dip 3 to 8 degrees southeast. One mile below is a small lignite bed underlaid and overlaid by chocolate sands. Below here the river makes a turn to the northeast and again intersects the same bed as is seen at Smithville. White Marl Bluff is near the Fayette county line, is ten feet high, and composed of interbedded strata of dark gray clay, glauconite, gray sand, and a creamy white shell-bearing calcareous marl. These beds vary from one to twelve inches in thickness, and are all highly fossiliferous.

Rio Grande Section.—In limestone from Laredo Professor Heilprin has found *Cardita densata*, *Turritella carinata*, and other Claiborne fossils. One mile below the town are seen highly calcareous sandstones, soft on a weathered surface, hard and flinty inside, and associated with chocolate clays. Large quantities of iron pyrites are found all through the formation, as well as specks of lignite, grains of glauconite, and often an efflorescence of sulphur. Five miles below Laredo, a large bed composed of fragments of an oyster was found in the following associations:

1. Oyster bed, containing fragments of oysters cemented in greensand marl..... 1–2 foot.
2. Softer greensand marl, with a few oysters, *Turritella*, shark teeth, etc..... 2 feet.
3. Interlaminated gray and chocolate sandy clay with sulphur..... 2 feet.
4. Greensand marl to water edge..... 1½ feet.

Below this point for five miles similar deposits are seen, and then we come to another highly fossiliferous bed, consisting of interbedded siliceous sands, chocolate clays, and greensand, in a bluff fifty feet high. Half way up is a bed composed mostly of shells in a greensand matrix,

* This is the locality referred to by Dr. Buckley "near Mrs. Gazeley's." First Annual Report, Geological and Agricultural Survey of Texas, S. B. Buckley, 1874, p. 64.

and eight to twelve inches thick. In it were found many oysters, *Turritella* and other gasteropods. Hard gray calcareous nodules, like those at "Bombshell Bluff," on the Colorado, and containing specks of lignite, are found throughout the section. One mile below, and on the Mexican side, is a bluff thirty to fifty feet high, and extending down the river for a mile and a half. It is composed of interbedded gray sands, with specks of glauconite, and chocolate and gray clays, containing thin lenticular seams of lignite one-eighth to one-quarter inch thick, and a few fragments of shells; also gray calcareous concretions one to two inches in diameter, and gypsum crystals. At its lower end this bluff runs into a somewhat similar formation, but differing from it in having many colored sands in seams of purple, red, yellow, brown, and bluish gray. Considerable quantities of iron pyrites are present, and it is probably to this that much of the coloring matter is due. Two miles below here the strata again assume their normal character, and dip two degrees southeast. About at the line between Webb and Zapata counties is a bluff a mile long, and reaching a maximum height of a hundred feet. It consists of buff and greenish-colored sands with gray calcareous concretions, one to ten feet in diameter, and many large gasteropods, one to four inches long, in a hard shell rock at the base. Near the top of the bluff is another shell bed, six to eight inches thick, lenticular, and made up mostly of fossils, among which are many *Turritella* and *Cardita*. Similar bluffs, but without fossils, are seen almost continuously down the river, on the Texas side, for two miles.

At the mouth of Arroyo Dolores are found glauconiferous beds with many oysters, in places made up entirely of them, with apparently no other fossils, and rising ten to thirty feet above the water. Thirteen miles above San Ignacio is seen a low reef of hard gray limestone, weathering to a greenish-gray color, and rising two feet above the water. It shows a concretionary structure in places, and forms rapids in the river. Four miles below this is a bluff three hundred yards long and varying from twenty to sixty feet high. The upper third of it is composed of river alluvium, with a pebble bed at its base. The lower part consists of buff sands and sandstones, with seams of chocolate clay and greensand. The top of this deposit is capped by a shell bed containing glauconite, and six to eight inches thick. Among the fossils were found *Cardita*, *Crassatella?*, oysters and shark teeth. The shell bed contains

specks of lignite, and the shells are mostly in fragments. Small white calcareous concretions are numerous. Dip, 1 to 2 degrees southeast.

Similar outcrops, but non-fossiliferous, are seen down the river to a point twelve miles below San Ignacio. The sandstones vary from very friable to hard and compact, and often loose masses lie on the slopes of the bluffs like slabs of flagstone. Throughout this whole distance of twenty-one miles the strata all dip to the northeast at an angle of from 1 to 10 degrees, and in one place, five miles below San Ignacio, they dip 10 degrees northwest. This is the greatest and longest variation in the normal southeast or east dip that has been seen by the writer anywhere in the formations under discussion. The strata do not show any other evidence of having been upthrown or disturbed in any way, and it seems probable that this abnormal dip is due simply to the natural sinking and contraction of the strata. Below here on the river are seen many local dips to the northeast of 5 to 8 degrees, but they never prevail for more than a mile or so. Four miles above the Texas town of Carrizo, and on the Mexican side of the river, is seen a bed of woody lignite one and a half to two feet thick, overlaid by ten feet of buff sands and underlaid to the water's edge by four feet of greenish-gray clay. The Rio Salado flows into the Rio Grande from the Mexican side opposite Carrizo. The town of Guererro is on this river, six miles from the mouth, and in this distance are seen many outcrops of buff sandstone, often rising in abrupt ledges through the river alluvium. Most of the houses, churches, and fences of the town are built of it. Similar rocks are seen for sixteen miles below Carrizo on the Rio Grande, and dip at an angle of 2 to 6 degrees southeast. At this point a small creek on the Texas side cuts through a series of low ledges of interstratified buff sandstones, containing gray concretions and chocolate black and greenish-blue semi-indurated clays, dipping 1 to 2 degrees southeast. In the bed of the creek were found many fossils, mostly oysters, and fragments of silicified wood. Thence down the river for nine miles similar, but unfossiliferous, ledges are seen. At the end of this distance is a bluff forty feet high, composed of interbedded hard and soft calcareous sandstones and clay seams, and containing many *Cardita* and *Crassatella*. Numerous calcareous concretions are found, and the sand occasionally contains coarse black and gray siliceous grains the size of a mustard seed and larger. Three miles below here, and half a mile above the Starr county line, is a low bluff composed of gray clay and capped by

a bed six to eight inches thick of shell rock with specks of glauconite, *Cardita*, and many gasteropods (*Turritella*, *etc.*) Eight miles below the western line of Starr county the following section was seen:

1. Indurated light brown sand..... 3 to 6 feet.
2. Loose light brown sand..... 10 feet.
3. Gray clay..... 5 feet.
4. Oyster bed, *Ostrea contracta?*..... 10 to 12 inches.
5. Gray clay..... 1 foot.
6. Oyster bed, *Ostrea contracta?*..... 1 foot.
7. Detritus to water edge..... 4 feet.

Beds 4 and 6 are a solid mass of shells. Some of the oyster shells are over one foot long. Dip of strata varies from horizontal to 3 degrees northeast. Eight miles above Roma are seen similar beds, associated with similar clays, and dipping 2 to 3 degrees south. Two miles below this point, on the Mexican side of the river, the following section was seen:

1. Greenish-yellow hard clay, with white calcareous concretions, gypsum, and sulphur, indurated in layers 1 to 3 inches thick..... 20 feet.
2. Oyster bed, same as described above, in a white calcareous rock.... 2 feet.
3. Same sands and clays as in 1..... 18 feet.
4. Brown and black lignitic clay, with gypsum and sulphur..... 6 feet.
5. Siliceous sandstone, rusty and hard in seams, gray to brown in color, and containing much sulphur as it approaches bed 4..... 10 feet.

Dip of strata 7 degrees southeast.

The bluff varies from ten to thirty feet in height, and is a half mile long; the above section is taken along three hundred yards of it. Two miles below this, on the Mexican side, is seen an oyster bed, in the same associations as in the above section. It is ten feet thick, and contains a seam of clay in the lower part. The bed immediately overlies the brown and black clays of the last section. Dip, 0 to 2 degrees northwest. Four miles below, on the Texas side, are seen ledges and reefs of similar shell beds, and in some cases single shells are as much as eighteen inches long. Dip, 5 degrees west. The same formation runs hence to Roma, but at that place only a few of the large oyster shells are seen scattered through the buff sandstone. One and a half miles below Roma are seen the same strata as at that town, and dipping 7 degrees east. At this point we come into a great clay and sand area, non-fossiliferous, and resembling the Fayette beds of the Colorado river.

YEGUA DIVISION.

To this division is referred the lower portion of the deposits heretofore classed as Fayette beds.

EAST TEXAS SECTION.—Following the Cook's Mountain beds, there comes a series of deposits made up chiefly of sands, sandy clays, clays and brown coal. The country occupied by them is, as a whole, low and flat, in few places of sufficient relief to present anything but the most superficial section.

In area this group extends from the Angelina river westward and southwestward across the Neches to the Trinity in Houston county. Eastward they probably cross the Angelina, and extend into and even across the southern portion of Nacogdoches, and may also be found west of the Trinity in Leon and Madison counties. The northern boundary, in the region crossed by this section, begins in Cherokee county, south of Atoi creek, and passes in a generally southwest direction along the margin of the Marine beds, about two miles south of McBee's school house, two miles south of Alto, and crosses the Neches river a little over three miles to the south of Robbin's ferry. Continuing its southwesterly course as far as Crockett, it bends more to the west for twelve miles, when it again turns south and across the Trinity river at Alabama bluff, where it forms the upper division of the section.

They are limited to the southward by a series of gray clays and gray sandstones, which occur about a mile south of the Neches, at Clark's crossing on the Houston East and West Texas railway, where they rest upon the heavy deposits of gypseous clay belonging to the beds under consideration. The sandstones also occur eastward at Rockland, on the Neches, ten miles north of Colmesneil, and to the westward they have again been crossed at Riverside, on the Trinity; but whether they rest upon the same gypseous clay has not yet been determined, as at neither of these places has the base of the sandstones been seen.

The upper portion of Lufkin deposits consists of gray, white and blue sands, sometimes laminated and cross-bedded, although the greater portion of them show no structure whatever. They are frequently saline, and in dry weather, the water having evaporated, the pools show heavy incrustations of salt. In many places they contain quantities of silicified wood, forming a strong contrast with the beautifully opalized wood of the succeeding deposits. Quantities of siliceous pebbles occur, at some places in small patches and at others in the form of thin, distinctly formed lines. These pebbles are mostly rounded and water worn, but are occasionally fragmental or angular pieces of an older rounded

boulder. Although they are mostly of quartz or silicified wood, occasional pieces of syenitic rocks have been found scattered through the mass, and many have a thinly stratified or laminated dark blue or black slaty appearance.

The principal bed underlying these sands, and the one probably forming the greater portion of the whole group, is a heavy bed of dark blue clay, changing to a dirty yellow, containing clusters of small crystals of gypsum in great profusion. It stretches from the Angelina southward to the Neches, on the south side of which it is seen passing under the gray sandstones of the succeeding group. Where it disappears this bed is thirty-five feet thick.

The basal deposit of this group is a dark blue laminated clay in the neighborhood of Alto, while in Houston county it consists of a dark blue laminated sandy clay, with partings of brown sand, and containing numerous crystals of selenite. In both cases the clays rest, so far as can be seen in the sections obtained, directly but unconformably upon the Marine beds. Whether these beds are the equivalents of each other can not, with the knowledge at present available, be accurately determined. Their connection may possibly be found in Trinity and the northern part of Polk county, but in the absence of any examinations in these counties nothing definite can be stated.

Another series of deposits which may belong to this group is a set of beds found in the valley to the south of New Birmingham and Rusk, in Cherokee county. These consist of several beds of thinly laminated gray and black sands and gray clay, a section at J. D. Baker's brickyard giving:

1. Brown sand and gravel, with small pieces of gravel and iron....2 to 3 feet.
2. Alternate strata of purplish gray clay and gray sand, the clay in strata of from six inches to one foot, and in places two feet, and the sand from one to six inches. Numerous fragments of leaves occur in this clay..... 8 feet.
3. Purple clay containing fragments of leaves..... 6 inches
4. White sand to bottom of pit..... 2 feet.

These beds do not belong to the other Eocene deposits found throughout the higher ground of the country, and may not belong to the group of beds under consideration. They are probably of estuarine, or perhaps fresh water origin, but beyond their existence nothing is yet positively known, and they have only been placed in this group tentatively on account of their overlying the Eocene beds in their neighborhood.

Another circumstance which adds to the difficulty of ascertaining the exact geological structure or position of these deposits is the great want of conformity between them and the underlying Eocene beds. Everywhere, where examined, this unconformability is so strong that one is led to the almost unavoidable conclusion that the Eocene had been subjected to a long continued and great erosion before the overlying clays and sands were deposited.

Brazos River Section.—As we descend the river from the "Moseley's Ferry" shell bed, which is the uppermost fossiliferous Tertiary bed seen on the river, we reach, at a point four miles below it and at the mouth of the little Brazos, a rapid caused by cross-bedded sands, with gray, black, and greenish clays in lenticular seams, and containing many ferruginous concretions. For over two miles below this are seen outcrops of gray sand and watery-green and chocolate clays, with brown coal beds up to one and a half feet in thickness. Many calcareous concretions, one-half to two feet in diameter, are seen, as well as hardened masses of clay and sand and a tremendous amount of silicified wood in loose blocks. This wood was not seen in place, but occurred in the gravel drift overlying this formation. Nine miles below "Moseley's Ferry," and in the eastern part of Burleson county, is "Sulphur Bluff." The following section shows the occurrence of the strata:

1. Light brown hardened sandy clay ..... 10 feet.
2. Brown coal ..... 1 feet.
3. Grand sand ..... 1 foot.
4. Brown coal ..... ½ foot.
5. Interbedded gray sand, and chocolate and greenish clay, turned white in places on the surface ..... 20 feet.

The whole bluff is coated with sulphur as at the "Chalk Bluffs" on the Colorado river. It is one mile long, 40 feet high, dips 3 degrees south, and presents a white and bleached appearance. Silicified wood is found in many places, and is similar to that described on the Colorado. From here to a point eight miles above the mouth of Yegua creek are seen small outcrops of the same sands and clays. At this point is seen a bluff showing the following section:

1. Cross-bedded gray sand, hardened in places ..... 10 feet.
2. Hard greenish clay, with seams of chocolate clay ..... 12 feet.
3. Brown coal ..... 1 foot.
4. Hard greenish clay ..... 6 feet.
5. Brown coal ..... 2 feet.
6. Calcareous gray sand, with indurations ..... 6 feet.

Dip of strata 1 to 6 degrees south. Many imperfect leaf impressions and considerable iron pyrites are found in the clay. Three miles above Yegua creek is seen a bluff of similar clays and sands.

COLORADO RIVER SECTION.—As we enter the country underlaid by these beds going down the Colorado, we pass a series of low bluffs, composed of dark gray or black clays, much jointed and faulted, until the mouth of Barton creek is reached. Here there is a bluff over 100 feet high and composed of clay and sandy strata, as represented in the following section:

1.	Red Quaternary gravel and sand	12 feet.
2.	Light brown sand and clay	16 feet.
3.	Lenticular bed of brown coal	1½ feet.
4.	Chocolate colored sand and clay, with gypsum and sulphur	10 feet.
5.	Brown coal	1 foot.
6.	Interlaminated beds of gray sand and clay of a black, chocolate or green color, with gypsum and sulphur	55 feet.
7.	Brown coal	2 to 4 feet.
8.	Similar strata to those of 6	3 feet.

The whole formation is much faulted and jointed, and dips 2 to 5 degrees southeast.

From here to within twelve miles, by river, of La Grange we pass over a series of outcrops of similar sand and clay strata, all dipping in the same direction, and frequently containing rusty masses of carbonate of iron. At this point we come to what is locally known as Chalk Bluff, on account of the resemblance of the hard clay to chalk. It dips 5 degrees southeast, and is 100 feet high. The following section is made up from different parts of the bluff:

1.	Pebbly Quaternary drift	10 feet.
2.	Laminated chocolate clays and sandy clays, white on exposed surface, or yellow with sulphur	100 feet.
3.	Woody lignite	5 feet.
4.	Same strata as 2	5 feet.

Numbers 2 and 4 contain large quantities of sulphur, coating the exposed surfaces and joint cracks as an efflorescence. Gypsum crystals are very plentiful throughout the beds. The lignite contains masses of partly silicified and partly lignitized wood. The associated clays also contain fragments of the same material. The whole bluff presents a white or yellow appearance, but on breaking through the outside crust the sands and clays regain their original dark color. At the foot of the bluff we find fragments of a hard light watery-green clay, of the consistency of talc. These pieces came from near the top of the ledge, and will

be mentioned further on. Low outcrops of the same materials are seen below this point until we come to the second "Chalk Bluff." This is about a quarter of a mile long, has a general dip of 3 degrees southeast, and is about the same height as the first one. The following section is made up from different points along the bluff:

1.	Quaternary drift.		
2.	Interbedded gray and white sand, white and watery-green clay	70	feet.
3.	Hard watery-green clay, like in 2	4	feet.
4.	Brown coal	2	feet.
5.	Similar strata to 2, light chocolate color on surface	3	feet.
6.	Brown coal	1	foot.
7.	Similar strata to 5	7	feet.
8.	Chocolate clays, with black leaf and reed impressions	⅓	foot.
9.	Hard watery-green clay	4	feet.
10.	Brown coal	1	foot.
11.	Hard light green clay	5	feet.
12.	Similar strata to 8	½ to 1	foot.
13.	Hard light green clay	6	feet.
14.	Brown coal	1 to 2	feet.
15.	Hard to light green clay	10	feet.

Leaf impressions are found in many places throughout the whole bluff, but especially in the two beds mentioned in the above section. Considerable gypsum and sulphur exist throughout the strata. The lumps of hard clay found at the base of the first Chalk Bluff are probably from a bed corresponding to the foot of this bluff. For two miles below here are seen small outcrops of similar strata, all showing a uniform southeast dip of about 5 degrees, and composed of green, gray, chocolate, and black clays or sands. In one place a brown coal bed over ten feet thick was seen. The river here is very crooked, and the same beds are cut by it in several different places. Four miles, by river, above La Grange is "Palm Bluff," about 100 feet high and covered in its lower half by a heavy bed of detritus. The upper half is composed of a series of light watery-green clay, with sand beds and calcareous seams.

Rio Grande Section.—The first undoubted beds of this series are seen five miles below the Texas town of Roma, and in the Mexican State of Tamaulipas. They occur in a ledge three hundred yards long and one to six feet high, and consist of hard light sea-green clays, with many leaf impressions and rusty iron pyrites. At the lower end they are overlaid by similar beds, but somewhat harder and more sandy. Frequently small white calcareous concretions, and sometimes large clay indurations

with veins of crystalline calcite, are found. Three miles below are found similar beds just above the water level.

FAYETTE DIVISION.

To this division are referred the Fayette sands proper.

The base of this division is somewhat conglomeritic in places and contains great numbers of a bivalve shell which is closely allied to *Macoma*, and which in some localities is accompanied by other forms, both gasteropods and bivalves. The upper line of demarkation is somewhat irregular, as the overlying Lapara beds rest upon it quite unconformably, and in places occupy basins eroded in it.

EAST TEXAS SECTION.—The greater proportion of the deposits, where seen, consists of gray sandstones interstratified with gray clays and gray sands, the last containing considerable quantities of opalized wood. A gray sandstone, containing fossil leaves as yet undetermined, occurs about one mile north of Corrigan, and the upper beds of the southern sandstones, near Bowers, contain numerous casts of palm leaves, reeds, etc. Some of the palm leaves are of great size, fragments measuring from three to four feet across being of frequent occurrence.

Three miles north of Corrigan, on the line of the Houston East and West Texas Railway, a deposit of white sandstone occurs, containing casts of shells. The fossils found here have been referred to the Eocene by Dr. Dall, on the strength of the existence of the casts of *Cardita planicosta*. *

The thickness of these sandstones and clays, as shown by the sections, is approximately 150 feet. Near Rockland they have a thickness of 200 feet; on the Neches, at Clark's Ferry crossing, 30 feet; the exposures on McManus creek, and other places near Stryker, are over 100 feet; in Hitchcock's quarry, near Corrigan, 20 feet; and westward, at Riverside, on the Trinity, they appear to have a thickness of over 100 feet in the river bluffs.

These beds were referred to the Grand Gulf (Miocene?) of Hilgard by Dr. Loughridge, and in previous reports of this Survey.†

*The other fossils of this horizon from this and other localities have been studied by Mr. Gilbert D. Harris and found to be characteristic Eocene species.

†Cotton Production of the Southern States, Tenth Census, Vol. 5, p. 21.

General section from Angelina river, in Angelina county, south to Corrigan, in Polk county:

1.	Coarse gray sand	50 feet.
2.	Laminated blue and white sand	15 feet.
3.	Brownish-gray to yellow sandstone, gradually losing its brown tint as it nears the base. The upper brown division is thinly laminated and contains plant impressions and nodules of pure clay. The lower gray division contains clay nodules, but no plants. four feet in railway cut, but fifteen feet in Hitchcock's quarry	20 feet.
4.	Gray sand	22 feet.
5.	White sandstone containing casts of *Venericardia planicosta* and other shells	2 feet.
6.	Indurated gray sand or soft sandstones	4 feet.
7.	Unknown. probably gray sands and sandstones	.....
8.	Gray cross-bedded sands	35 feet.
9.	Gray sands with quantities of opalized wood	25 feet.
10.	Laminated pink clay	6 feet.
11.	Gray laminated sand	4 inches.
12.	Gray sand stained brown	1 foot.
13.	Thinly stratified gray sand	1 foot.
14.	Gray sandy clay	3 feet.
15.	Gray sandstone	3 feet.
16.	Shaly gray clay	1 foot.
17.	Gray and yellow sand	3 feet.
18.	Light yellow or cream colored clay	2 feet.
19.	Thinly laminated gray sandstone	3 feet.
20.	Brown laminated clay	3 feet.
21.	Thinly stratified white and gray sandstone	1 foot.
22.	Gray sandstone stained brown	3 feet.
23.	Thinly stratified or laminated blue clay with gypsum in crystals.	35 feet.

Brazos River Section.—Three miles above Yegua creek is seen a bluff of clays and sands, and a quarter of a mile below that creek, in Washington county, are seen ten feet of light green clay capped by one-half to one foot of hard gray cross-bedded sandstone. The sandstone lies unconformably on the clay and contains lumps of the latter, proving that the increase in the speed of the waters, that caused the character of the deposit to change from a clay to a sand, had also eroded part of the clay and deposited lumps of it in the sand. A mile and a half below this is a low bluff showing similar sands, composed of coarse transparent white, red, and black grains, with pebbles of the same composition, and one-eighth to one inch in diameter. There are also found in it worn pieces of silicified wood one to six inches long, with similar fragments of vitreous wood opal; lumps, singly and in lenticular patches, of light green clay, one-quarter to two inches in diameter; rusty crystals of iron

pyrites; worn pieces of bone, one-half to two inches long; small shark teeth, worn and broken; and small white calcareous nodules. The sand is cross-bedded, and in places hardened into a friable sandstone. The organic remains in this bed have doubtless been eroded out of the Tertiary strata and laid down here during the deposition of the sands, as they have evidently been much worn and rolled, and the shark teeth strongly resemble Tertiary forms. A mile and a half below this is a hill rising one hundred feet above the river bottom, and closely resembling the LaGrange bluff. It shows the same friable sandstones, coarse and fine sand, loose yellow sandy clays with white calcareous nodules, iron pyrites, etc.

Colorado River Section.—The upper thirty feet of Palm Bluff is composed of sand, in places hardened into a friable sandstone similar to those already described. It is composed of sharp siliceous grains, and often contains black specks. Patches of very coarse transparent sand, the size of a mustard seed and larger, occur in it. Lumps of white or light brown clay and similar nodules of limestone, from one-half to one inch in diameter, are of frequent occurrence. In some places black oxide of manganese coats the grains of sand. Many impressions of a palm or palmetto leaf, as well as silicified stems and trunks, are found in the sand bed. From here to LaGrange are low outcrops of the same sand as caps Palm Bluff. They are of a very striking light watery-blue color when wet, but gray when dry.

"LaGrange Bluff" is about a mile below the town of LaGrange. It is 100 feet high, and the lower part is heavily covered by alluvium and detritus from above. The exposed part is composed of interbedded soft friable sandstones, white or yellow in color, specked in places by rusty spots of decomposed iron pyrites, and containing many small white calcareous and clay nodules. The whole bluff offers very much the same appearance as "Palm Bluff," and the sand varies from a very fine variety to that of the size of a mustard seed. Frequently a hard clay is interbedded with the sands, and when dry often weathers into nodules, due to its conchoidal fracture. The white calcareous nodules are in places so numerous that they form a conglomerate, with sand or yellow sandy clay as a matrix.

Rio Grande Section.—Eight miles below Roma are found similar beds just above the water level, and overlaid by fifteen feet of sandstone, with

concretions, fragments of worn silicified wood, and a few broken pieces of an oyster. These latter have the appearance of being derivative and not indigenous to the bed, as they are much rounded and rolled, and were very probably derived, during the deposition of the enclosing clays, from the great oyster beds of the strata about Roma. Two miles below this are seen similar beds, but with no clay, the soft and indurated layers alternating with each other. The dip is 2 degrees north 20 degrees east. This, however, is a local variation. Nine miles above Rio Grande City are seen similar sands with silicified trunks and branches of trees. The sands have the characteristic grains seen in the Fayette beds on the Brazos and Colorado.

The town of Rio Grande City (Ringgold Barracks) is situated on a bluff of hard white clay, rising some fifty feet above the river, and indurated into a substance of a chalky consistency, though, chemically, it is only very slightly calcareous. It probably represents the light green clays of the Fayette beds, and has become indurated by exposure to heat in a dry climate. The effect of such agencies would also account for its white appearance, as the characteristic pale green color of these clays is doubtless due to their hydration. The bed shows a highly conchoidal fracture, contains iron pyrites, and is much jointed. These joint cracks are frequently filled by veins of smoky quartz one-eighth inch to one inch thick, often showing a globular surface. The bluff extends along the river for half a mile below the town, and two hundred yards above it. Beyond these limits it disappears under the gray river silt.

CHAPTER VII.

OCCURRENCE AND COMPOSITION OF THE BROWN COALS OF THE TERTIARY.

The lowest deposits of brown coal which are now known, and some of the heaviest and best beds as well, occur in connection with the Lignitic or lower portion of the Timber Belt division, the general stratigraphy of which has just been given.

The known occurrences begin in Bowie county, near Red river, and extend southwest through the counties of Cass, Marion, Harrison, Morris, Titus, Hopkins, Camp, Upshur, Wood, Rains, Van Zandt, Smith, Henderson, Anderson, Freestone, Limestone, Leon, Robertson, Milam, Lee, Bastrop, and Caldwell. From this point the deposits are not known until we reach Atascosa and Medina counties, where we again find the coal, and whence it can be followed westward to the northern part of Zavalla county, in which, at the Nueces river, the western boundary line turns south, through Dimmit county, until it strikes San Lorenzo creek, which it follows through Webb county to the Rio Grande. The existence of the brown coals throughout this area is shown by many outcroppings and numerous well borings.

Concerning the most northeastern of these occurrences—that of Bowie county—little is known beyond the general fact that outcrops are common along Sulphur Fork and also on Anderson's creek. The only work that has been done on it which has come under the observation of the Survey, is that by Mr. E. P. Elliott of New Boston. A shaft, some thirty feet in depth, was sunk on the Solomon Poer headright, which is on Anderson creek, seven miles south of New Boston, and the bed of brown coal penetrated showed a thickness of twelve feet. Specimens of this brown coal were sent to the Survey, and the analysis proved it to be of such excellent quality for gas coal that Mr. Elliott was advised to try to put it on the market for this purpose. The following analysis gives its proximate composition:

Moisture	10.67
Volatile matter	76.41
Fixed carbon	10.62
Ash	1.45
Sulphur	.85
Total	100.00

This brown coal is of black color, and its structure is somewhat earthy but irregularly fibrous, with the lustre of raw silk, in places shining. Some sulphide of iron occurs in it.

An analysis of another specimen from this same locality gave the following proximate composition:

Moisture	11.55
Volatile matter	37.70
Fixed carbon	42.30
Ash	7.55
Sulphur	.90
	100.00

In the northeastern portion of Cass county some work was done a few years ago in the vicinity of Alamo and Stone Coal Bluff.

The Alamo brown coal appears to be divided into two beds, one at forty-nine feet and the second at sixty-five feet. A section of the shaft shows:

1.	Sandy clay	26 feet.
2.	Gray clay	23 feet.
3.	Brown coal	1 foot 8 inches.
4.	Gray sand	2 feet.
5.	Hard slaty clay	9 feet.
6.	Brown coal	4 feet 2 inches.

The lower brown coal bed was not cut through.

The shaft was sunk by a company, with the intention of mining the brown coal of the lower bed, but, owing to difficulties encountered, the undertaking had to be abandoned. The quantity of water accumulating in the shaft contributed largely to the suspension of work of the company.

The Stone Coal Bluff brown coal lies in the bottom of the river, and the exposure can only be approached at low water. Dr. G. G. Shumard reports this bed of brown coal as having a thickness of twelve feet, gives the following analysis of it by Dr. Riddell, and speaks of it in the highest terms:*

* Shumard, Dr. B. F. First Report of Progress, p. 12.

Moisture at 212 deg. F	15.808
Volatile matter	39.422
Fixed carbon	39.788
Ash (grayish brown)	4.992
Total	100.000

Specific gravity, 1.483.

No specimens of this coal have been analyzed by the present Survey.

In Morris county deposits of brown coal are reported as existing along the banks of Sulphur Fork on the northern boundary of the county, and at various other places lying north of Daingerfield. These have not yet been visited and examined.

On the Jonathan N. Bohonan headright, about five and a half miles south of Daingerfield, there are several exposures of a thin seam of brown coal. At Mr. S. H. Pruitt's house an attempt has been made to develop this vein, and an opening has been made with a view to mining the coal for local use. The vein at this place is only fifteen inches thick, and dips a few degrees south of east, and according to Mr. Pruitt, at the rate of one inch in three feet.

A section of the opening at this place shows the following:

1.	Yellow sand	7 feet.
2.	Brown coal	1 foot 3 inches.
3.	Black or dark blue stratified sandy clay, mixed with lignitic matter, visible	5 feet.

The brown coal at this place, although reported as being of a fair quality, can not be worked.

The following is an analysis of it:

Moisture	4.45
Volatile matter	52.05
Fixed carbon	15.15
Ash	28.35
	100.00

The brown coal from the Pruitt mine is approximately a pitch coal. Its color is black to brownish black. Structure generally massive, but lamellar at times, with cubical fracture; some pyrites present. Lustre dull to pitchy; does not soil the fingers. No woody structure observed in body of coal.

A proximate analysis of selected specimens gave the following results:

Moisture	8.55
Volatile matter	41.24
Fixed carbon	40.89
Ash	7.10
Sulphur	2.22
	100.00

No shafts have been sunk or borings made below this to ascertain whether or not the heavier beds, which are those cropping out on Sulphur Fork, occur below these thinner ones.

From Franklin and Titus counties we have had no specimens, but from the work done in Hopkins county some years ago we have record of the existence of brown coal of excellent quality.

These deposits of brown coal are from ten to twelve miles from Sulphur Springs and near the surveyed route of the northeastern extension of the Houston and Texas Central Railroad. The surrounding country is quite broken and the brown coal outcrops in many places in the ravines and on the hillsides.

A shaft was sunk on the seam several years ago, and General W. H. King furnishes the following section of it:

1.	Clay	6 feet.
2.	Sand rock	10 feet.
3.	Slaty clay	4 feet.
4.	Brown coal	16 feet.
5.	Sands and clays	9 feet.
6.	Plastic clay	30 feet.

The clay or slate above the brown coal is is said to form a very solid roof.

The following proximate analysis shows its proximate composition:

		Everhart.
Water at 100 C	10.20	22.92
Volatile matter	39.92	50.28
Fixed Carbon	44.13	21.66
Ash	5.75	5.14

Sulphur was not determined.

The deposits of Marion county are also but little known. Good exposures occur on Big Cypress, and in the deep well at Jefferson three beds of brown coal were passed through at different depths. Many deposits are known along the north side of Caddo lake, outcropping in channels of the streams which enter the lake on that side, and are also found in wells in the vicinity. For the most part, however, they are not of sufficient thickness where they have been observed to be of any value for

mining, fifteen to eighteen inches being the maximum so far as noted by members of this Survey. Their areal extent has not been determined, nor has any analysis been made of them in the laboratory of the Survey.

In Harrison county the semi-lunar region of gray sands lying along the Sabine river, extending across the eastern side of the county and along the Caddo lake and Cypress bayou towards Jefferson, is generally underlaid by beds or deposits of brown coal of varying qualities, extent and thickness. As a general thing these deposits are thicker toward the southern side of the county than toward the north, and as far as could be judged from the well borings in which brown coal occurs, the deposit thins out toward the western margin of the gray sand area. These deposits are also, from the same data, irregular in their distribution, and are altogether absent in some localities.

Brown coal appears at several places along the Sabine river, in thicknesses of from two to six feet. On the John D. Pinson headright it is said to have a thickness of between five and six feet. Towards the centre of the area wells dug deep enough to pierce the brown coal beds show them to have a thickness of only from six to twelve inches. On the W. D. Ward headright the brown coal lies under thirty feet of sand and clay, and the mean of three wells does not exceed two feet, and along the lake shore region around Port Caddo the bed has a general thickness of about three feet.

Outside of the gray sand region the brown coal occurs at several places. In the deep well bored at Marshall brown coal about one foot thick was passed through at a depth of one hundred feet. It was also struck in a well on the O. H. P. Bodine survey at a depth of thirty-two feet, and on the Francis Wilson headright it is seen in a stream bed to have a thickness of two feet at a depth of seventy-six feet.

The bed found on the O. H. P. Bodine headright is the upper or highest bed found in a boring made near the same place under the direction of Mr. Hoxie, when general manager of the Texas and Pacific Railway. The drill was carried down eighty feet, and in its course passed through three beds or deposits of brown coal, showing thicknesses of twelve, six, and six feet. The lowest bed was not pierced through, owing to the quantity of water accumulating in the well, and the inadequate means of pumping at hand. While this bed is known to have a thickness of six feet, its actual thickness may be much more.

At Rocky Ford, on the Sabine river, the brown coal stretches across the river in the form of a bar, and disappears under a deep covering of gray sand. This bar of brown coal has a width of about forty feet and slopes downward in its passage across the stream, being about three feet higher at its upper edge than at the lower. The coal from this place is dark black in color, devoid of lustre, and friable when exposed to atmospheric agencies. In burning it has an unpleasant odor and leaves a soft brown ash. The thickness of this bed is said to be four feet.

A section of the place gives the following:

1.	Light yellowish gray silty sand	20 feet.
2.	Brown coal	4 feet.
		24 feet.

Except in very dry seasons this bed is always covered with water.

Near Carter's Ferry, on the Carthage road, there is another exposure of brown coal about six feet thick. This deposit, like the one at Rocky Ford, also stretches across and is best seen in the river bottom. The water here has cut a channel through the brown coal bed close to the Harrison county side, and leaves a wide stretch of the bed along the Panola county side of the stream perfectly dry. This brown coal is a dull black, with little or no gloss when freshly broken, and has a tendency to split into thin layers, and when broken across the strata breaks with a subconchoidal fracture.

In this deposit there are the trunks of two trees, measuring sixteen and twenty feet in length respectively, and from eighteen to twenty inches in diameter. The sixteen foot tree is silicified throughout its entire length, and the twenty foot tree is but partially so, having the butt and lower part of the trunk silicified and the top and upper part of the trunk perfectly lignitized. There does not appear to be any definite line of demarkation between the two conditions—the silicified and the lignitized—but they graduate from the one to the other almost imperceptibly. These trees are lying in such positions as they would take naturally had they floated down the river and sunk in the positions found. In this same bed there is a stump standing in such a position as to lead to the inference that it grew in the position it now stands, or was there prior to the deposition or formation of the upper three feet of the brown coal. This stump is silicified, and the centre has apparently decayed and been removed before the process of silicification had commenced.

The following is a section of the river bank at this deposit:

1.	Gray silty sand, forming the banks of the river on both sides	25 feet.
2.	Brown coal, dull and lustreless, thinly bedded and containing fossil trees	6 feet.
		31 feet.

At Robertson's Ford a section of the river bank gives:

1.	Gray sand	1 foot.
2.	Mottled, brown, blue, and yellow unstratified clay	45 feet.
3.	Brown coal	6 feet.
4.	Dark blue sandy clay to water	3 feet.
		55 feet.

This deposit is six feet thick, and is of a harder nature than the two deposits described above. When freshly broken it shows a slight lustre, which it soon loses, and breaks into an irregular lump resembling bituminous coal. This deposit appears upon the Harrison county side of the Sabine river and close to the water, even in its lowest stage. It is said another deposit occurs from twelve to fourteen feet deeper. The deposit as seen in the bank of the river has a length of about 100 yards, and in passing back into the country appears to thin out rapidly, as a well forty-four feet deep, about a mile north of the river, passed through only one or two inches of lignitic matter and into the blue sandy clay bed which underlies the brown coal at the ferry.

The deposit on the Francis Wilson headright is only two feet thick and about seventy-six feet underground, and is a true lignite, as the grain and fibre of the wood are still visible and can easily be traced. In texture it has all the appearance of a member of the pine family.

This lignite does not burn so readily as the others, but acts very like a wet wood. The smell from the fire is not so strong, but in other respects, such as showing a red ash, it is similar to the other brown coals of the district. In splitting and breaking it splits easily along the fibre, but breaks only with considerable difficulty, and then only with an even fracture.

Section of brown coal bed in stream on O. Hendricks survey near Port Caddo:

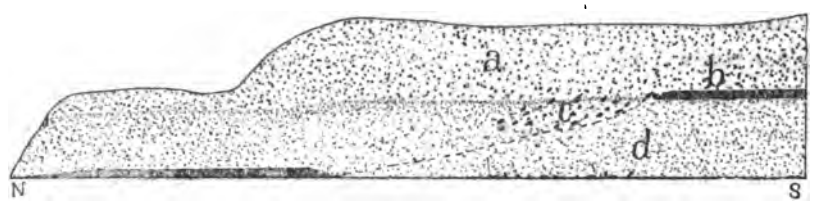


Fig. 9.

a, Gray sand. b, Lignites. c, Sandy pebbles. d, Rusty gray sand.

The brown coals from the Lake Caddo region are a dull, lustreless black. They have not yet been examined with regard to their action under fire.

ANALYSES OF BROWN COAL AND LIGNITE FROM OUTCROPS IN HARRISON COUNTY, TEXAS.

Number.	Water.	Vol. matter.	Fixed Car.	Ash.	Sulphur.	Total.
704.....	14.850	38.520	39.605	6.175	0.850	100.00
707.....	13.350	42.820	35.670	7.000	1.160	100.00
717.....	16.400	35.950	44.750	2.300	0.600	100.00
952.....	10.050	33.310	35.860	18.700	2.080	100.00

NOTE.—No. 717 is of the nature of lignitized wood.

Localities.

No. 704. B. Anderson headright, Robertson's Ferry, Sabine river. Pitch coal, sub-conchoidal fracture, lamellar to massive structure, color brown to pitch black.

No. 707. J. T. Ramsdale headright, Rocky Ford, Sabine river. Pitch coal; color pitch black, fatty streak under finger nail, compact, massive, no wood structure or lignitic matter visible. Fracture uneven. Contains occasional extremely thin layers and spots of a steel gray color of decomposed pyrites. Shrinkage cracks approximately parallel and perpendicular to plane of bedding. Does not soil the fingers.

No. 717. Francis Wilson headright. Lignite, passing into pitch coal, but with woody structure well developed.

No. 952. Port Caddo headright, McCathern creek, Hendricks survey. Lignitic brown coal, with mineral charcoal, also brown coal passing into pitch coal; laminated structure, brown or black in color.

A selected specimen of air dried brown coal from the Ramsdale headright gave the following analysis:

Moisture	9.50
Volatile matter	41.25
Fixed carbon	38.90
Ash	8.35
Sulphur	2.00
	100.00

At Athens, the county seat of Henderson county, are seen sandy and clayey strata similar to those described in Van Zandt county. The following section, made up from data collected to the east and southwest of the town, shows the character of the beds:

1.	Ferruginous clayey sand, with thin seams of iron ore, two to twelve inches thick	5 feet.
2.	Gray clays and ferruginous sands	23 feet.
3.	Potter's clay	12 to 18 feet.
4.	Siliceous sands and gray clay, in same places pure, in others ferruginous	78 feet.
5.	Brown coal	2 to 4 feet.
6.	Chocolate colored clay	3 to 4 feet.
7.	Gray clays and sands at base of section.	

The greater portion of the central and western portion of the county is underlaid by lignitic deposits. The brown coal outcrops at various places in the neighborhood of Athens. When first taken from the mines it forms a solid block with a subconchoidal fracture and slightly coal-glossy lustre, but upon exposure to the air for a few days it loses its gloss and becomes a dead black, and in a short time breaks into small cuboidal fragments.

The Texas Fire Brick and Tile Company mined and used as a fuel for steam purposes brown coal from an outcrop on the southwest corner of the C. M. Walters headright. The following is a section of this opening:

1.	Gray sand	6 feet.
2.	Yellow clay	2 inches.
3.	Brown coal	6 feet.
4.	Dark blue clay	4 feet.
	Total	16 feet 2 inches.

In mining this brown coal the overlying sand and clay were taken off and thrown into the hole left by the extraction of the coal. The product obtained was used as a fuel for some time, and is reported as being a good steam producer when carefully watched. It has also been used successfully both in Dallas and Corsicana for steam purposes, and at Athens for domestic uses and for firing brick kilns.

The following analyses made in the laboratory of the Geological Survey were from two specimens from the same bed, No. 1 being a freshly mined specimen, and No. 2 a specimen taken from the Survey Museum, where it had been kept for more than two years:

Locality	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
No. 1, C. M. Walters headright	6.80	50.65	37.00	5.55	0.52
No. 2, C. M. Walters headright*	5.70	57.45	29.85	7.00	0.87

*Collected by Dr. R. A. F. Penrose, Jr.

Brown coal also occurs in a bluff on the north side of the S. Calderon headright. The following is a section of this bluff:

1. Brown sand ..... 10 feet.
2. Thinly laminated sandy clay ..... 14 feet.
3. Black sandy clay ..... 2 feet.
4. Brown coal (exposed) ..... 10 inches.

Total ..... 26 feet 10 inches.

On the Neches river, about two miles east of this place, brown coal occurs in the bluffs of the river, extending southward for nearly a mile, and is also found in wells throughout the southeastern portion of the county at depths ranging from twenty to forty feet.

In nearly every part of Smith county beds of brown coal are found, varying in thickesss from a fraction of an inch to ten feet. These beds are very numerous and lenticular in shape, having uniformly a dip to the south or southeast. The physical aspect of the brown coal varies considerably. It differs in color from brown to black and from an amorphous mass to a hard glossy variety.

In the northern part of the county it is developed in great abundance along the Sabine river, and may be seen cropping out in many places in its bed and bluffs. It is also met with in the southern portion of the county. On the William Luce league a section of the strata gives:

Red sand ..... 10 feet.
Blue clay, containing the seams of lignite and yellow sand ..... 6 feet.
Sand, impregnated with lignitic matter ..... 5 feet.
Blue clay ..... 6 feet.
Brown coal exposed to view ..... 3 feet.

The coal was brownish black, massive, uneven to sub-conchoidal in fracture and contained small inclusions of resin and also of the steely gray sulphate of iron. Shrinkage cracks irregular. No traces of woody structure.

On section twenty-four of Thomas Quevedo survey the following section was seen:

Soil ..... 3 to 5 feet.
Buff colored sandy clay ..... 10 feet.

Red and white mottled clays, with streaks of sand	20 feet.
Blue sandstone	6 inches.
Brown coal	4 feet.

This specimen was very similar to the above, except that it was browner in color and contained no inclusions of resinous matter.

Other localities are west of Lindale, three miles northeast of Lindale, sections 6, 24 and 40 of Seven Leagues, E. E. Lott headright, and in the Sabine river close to Belzora crossing.

The brown coal beds are generally overlaid by from two to thirty feet of sand and clays, and can only be seen where the creeks and rivers have cut through the overlying strata.

In their natural state the value of these brown coals is quite small, on account of the large amounts of ash, sulphur, and water which they contain, a great part of the heating power being thus lost. The following is the analysis of five of these brown coals:

Locality.	Number.	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	
Eight and a half miles southwest of Tyler	1	14.23	43.07	30.82	10.62	1.26	100
Three miles west of Lindale	2	9.83	32.45	16.10	40.22	1.70	100
Twelve miles southeast of Tyler, Wm. Luce survey	3	11.70	43.57	27.76	16.38	.59	100
Lee Springs, six miles south of Tyler	4	3.80	26.85	11.80	57.55	(*)	100
Three miles northeast of Lindale, Robinson survey	5	11.40	40.90	35.50	14.20	(*)	100

*Not determined.

Nos. 1 and 5 are fair average samples of the brown coals found in Smith county.

The lignitic series of sands, clays and lignites appear in Gregg county at various places along the Sabine river. No deposits of brown coal of sufficient thickness to be of any practical value were seen.

Some years ago shafts were sunk on the H. Frost headright for the purpose of mining the brown coal deposits underlying the sandy deposits. Several tons were mined and used as fuel on the Texas, Sabine Valley and Northwestern Railway. No satisfactory test was made, as this fuel was abandoned on economical grounds, brown coal having been found, under the conditions existing at that time, a more expensive fuel than wood. The pits were deserted, and are now filled up with sand and water.

Where the International and Great Northern Railway crosses the Sa-

bine river the northern bank shows a section of thirty feet of sands, brown coal and clays, capped by about twenty feet of ferruginous and siliceous gravel, sand, and small nodules of iron ore.

The following is a section at this place:

1.	Brown ferruginous sands and gravels	20 feet.
2.	Dark greenish gray micaceous sands	15 feet.
3.	Thin seams of earthy brown coal, with alternate strata of dark colored sand, the main seam of brown coal one foot thick	5 feet.
4.	Bluish colored sandy clay to water	8 feet.
		48 feet.

The bluff at Iron Bridge Postoffice is made up chiefly of alternate strata of sand and soft yellowish brown sandstones or altered greensand. No brown coal appears in this section.

Brown coal is reported as being visible at different points along the river at low water.

Brown coal occurs in Upshur county about six miles northeast of Gilmer, near Childress Mountains. Some attempts to work the deposits have been made, but so far the Survey has had no specimens from the locality given.

In Wood county the brown coal deposits examined occur mostly on the western side of the county near Alba station, on the Missouri, Kansas and Texas Railway. In this region there are three distinct deposits of brown coal. First, the upper bed cropping out close to the Alba Coal Mining Company's shaft, a second one near Alba, and a third a short distance north of that village. These deposits cover a known area of sixteen square miles, and while nothing is positively known about the two lower beds, the upper has a thickness of eight feet at the Alba mine, but thickens on the dip. A section of the Coal Mining Company's shaft shows:

1.	Gray surface sand	6 feet.
2.	Blue shaly (laminated) clays	12 feet.
3.	Brown coal	8 feet.

Half a mile south the section of a well shows the brown coal to have thickened to thirteen feet and to have gone down forty feet from the surface.

The Alba Coal Mining Company own or control about one thousand acres of this area, and are engaged in mining the brown coal, drawing their supplies altogether from the upper deposit. This company commenced work in February, 1890, but did not ship any of their product

until May of that year, and since that time have been making irregular shipments of the coal, their markets being chiefly Fort Worth and Dallas.

The mine is situated about half a mile east of the village of Alba, on the Missouri, Kansas and Texas Railway, and the brown coal is reached by a shaft twenty-four feet deep. Of the eight feet of coal about six feet are mined and the balance is left overhead to form a roof. Five drifts have been made into the bed, in various directions, ranging from 150 to 265 feet each. These drifts are six feet wide, and in some places roughly formed rooms from nine to twelve feet wide have been cut into their sides. The mine is ventilated by a few eight-inch air shafts sunk from above, but no difficulty has ever been found on account of foul air or gas. The mine is perfectly dry even at the face, although no provisions have ever been made for draining. The roof is solid, and no timbering has been used in any portion of the mine except in the shaft and one or two props in one of the largest rooms.

The work at this mine has been carried on intermittently, and no coal is mined until an order is received. The facilities for mining these deposits are good, and a much greater amount can be obtained when a demand arises for this class of fuel.

The Alba mine contains brown coal with lignites. The coal is brown to black in color, passing in places to pitch coal, of massive structure, and jointed perpendicularly to plane of bedding. The lignites contained in it preserve perfectly their woody structure.

Proximate analyses were made of fresh coal and an air-dried specimen, with the following results:

	Fresh coal.	Air-dried.
Moisture	10.85	6.15
Volatile matter	37.82	42.01
Fixed carbon	38.21	41.71
Ash	12.35	9.35
Sulphur	0.77	0.78
	100.00	100.00

The relations of the deposits of brown coal to the interstratified clays and sands are shown by the section of the well at Mineola, page 133.

A specimen of brown coal from Mineola is of black color, varying to a very dark brownish-black, firm, and does not soil the fingers. In transverse section it shows slight lamellar structure. Streak glistening. No wood structure visible except in horizontal section, where slight carbona-

ceous markings resemble, very imperfectly, leaf remains. Some seams or detached particles of much brighter lustre were also observed. Shrinkage cracks usually either along lamellar markings or perpendicular to them. A proximate analysis gives the following composition:

Moisture	12.00
Volatile matter	38.94
Fixed carbon	39.78
Ash	8.55
Sulphur	73
	100.00

Large deposits of brown coal also occur in the neighborhood of Hawkins station, on the Texas and Pacific Railway. This field is said to cover over a mile of territory, but its actual extent is not known.

In Rains county the brown coal crops out in many of the bluffs, and is of excellent quality, as will be seen from the two analyses given.

A specimen of pitch coal taken seven miles east of Emory, Rains county, is of black color, lustre dull to bright pitchy, massive, firm, compact, with fatty streak. Few distinct laminæ of lighter lustre. Fracture unevenly cubical. Shrinkage cracks apparently parallel with or perpendicular to plane of bedding. This coal seems denser than most of those submitted for analysis. Does not soil the fingers.

A second specimen collected at Emory is very similar to the preceding, except that in fracture it seems to be flatly conchoidal and is somewhat brownish on exposed surface.

The analyses are as follows:

	Emory.	Seven miles E. of Emory.
Moisture	9.50	10.75
Volatile matter	38.70	40.35
Fixed carbon	36.75	36.45
Ash	14.15	11.45
Sulphur	.90	1.00
	100.00	100.00

The structure of the deposits of Van Zandt county is best exhibited by the borings of the wells made for the purpose of obtaining salt from the underlying deposit. A section of the Lone Star well, close to the Grand Saline station, gives:

		Thickness.	Depth.
1.	Brownish gray sandy clay	26 feet.	26 feet.
2.	Brown sand	8 feet.	34 feet.
3.	Sand and gravel	3 feet.	37 feet.
4.	Black shaly clay	20 feet.	57 feet.
5.	Brown coal	3 feet.	60 feet.
6.	Sandy shaly clay	20 feet.	80 feet.
7.	Sand and water	5 feet.	85 feet.
8.	Sandy clay shale	65 feet.	150 feet.
9.	Sand and water	14 feet.	164 feet.
10.	Hard white sand with a vein of salt water, five per cent salt	14 feet.	178 feet.
11.	Hard sand rock	6 feet.	184 feet.
12.	Shale containing pyrites	4 feet.	188 feet.
13.	Blue limestone, mixed with streaks of sand and gray limestone, but blue forming chief deposit	42 feet.	230 feet.
14.	Gypsum	5 feet.	235 feet.
15.	Rock salt	124 feet.	359 feet.

Brown coal beds were seen in large number of outcrops in Van Zandt county, where they appear in many places along the Sabine and the creeks draining into it. They are also found in digging wells almost all over the county, until the Cretaceous formation is reached near its western border.

The following section is on Little Saline creek, seven miles north of Canton:

Gray plastic clay	6 feet.
Brown coal	1–1½ feet.
Chocolate colored and black lignitic clays	5–6 feet.
Brown coal to bed of creek and still in bottom	2 feet.

The brown coal is sometimes in lenticular deposits, and is occasionally interbedded with dark brown lignitic clays, which turn a light buff color when burned. The dip in the above section varies from horizontal to a gentle incline to the southeast. The lignitic clays come to the surface in many places in this locality, though often covered by a variable thickness of sand.

Below is a section in the well of Joel King, ten miles northeast of Canton:

Surface sand	1 foot.
Gray and plastic clay	8 feet.
Red sand	5 feet.
Dark blue marl	10 feet.
Lignitic clay—dark gray, shaly	20 feet.
Brown coal	2 feet.
Lignitic clay—chocolate colored	5 feet.

The lignitic clays are often of a gray slate color, partly indurated, and of a shaly or slaty structure.

Going west along the line of the Texas and Pacific Railroad, the brown coal beds are found to end east of Wills Point, the most westerly deposit heard of along that line being found in a well on the property of James Moore, about seven miles east of the town.

In Freestone county brown coal occurs in a branch of Tehuacana creek, a few miles west of Fairfield, and is found in digging wells throughout the region. In the vicinity of Wortham the brown coal outcrops in the the branches, and boring has shown that there are three beds in the vicinity, of which the second is reported as having a thickness of five feet.

Brown coal occurs in the southeastern portion of Limestone county, and is a continuation of the beds of Freestone county. On Head's prairie the best exposures were found, and here a considerable amount of work has been done. Dr. Buckley gives the following analysis of brown coal from this locality, as made by Prof. Maurie of Chicago:

Moisture	12.00
Volatile matter	42.00
Fixed carbon	32.00
Ash	13.00
Total	100.00

At Bear Grass, in the northern part of Leon county, there is an exposure of coal in a ravine. The exposure is three hundred feet long. A well sunk on the bank of a ravine reached the coal at twenty feet and penetrated it to a depth of nine feet. It is also reported at many other localities between the Navasota and Trinity rivers. Coal deposits are also found southeast of Centreville and in the Trinity river bank opposite Hyde's Bluff, in Houston county, of which deposit it is the continuation.

Brown coal from the vicinity of Jewett is of a black color, with brownish shades in places; somewhat lamellar in structure, with laminæ of brighter and duller lustre alternating irregularly; firm, but soiling the fingers when rubbed on face of laminæ.

Lamellar faces show distinct traces of vegetable matter in the form of portions of leaves and stems, but in the form of vegetable carbon, as is seen in coal and not lignitized. Small particles of earthy material also occur in it. Shrinkage cracks parallel with lamellar structure or perpendicular to it.

Proximate analysis of an air-dried specimen from outcrop:

Moisture	10.35
Volatile matter	39.03
Fixed carbon	43.25
Ash	6.87
Sulphur	0.50
Total	100.00

The fresh coal contained 14.67 per cent of water.

The brown coal deposits extend through Robertson county from the eastern boundary in a west by south, or nearly southwesterly direction, to the Brazos river, and comprises an area of almost one-third of the entire county. The northern boundary of the area is approximately coincident with and extends across the northern line of the county, and the southern limit of the field lies along a line extending from the Navasota river westward to Owensville, and then along the northern bank of Muddy creek to the Brazos river, near the mouth of Little river, in Milam county. This region embraces Tidwell, Beck, Head, Heard, and Bald prairies, together with a series of other small prairies lying across the centre and throughout the northern portion of the county.

Throughout the whole of this area brown coal occurs in greater or less quantities at various depths. In the northwestern portion of the county the beds are represented merely by thin seams of lignitic clay and laminæ of lignite, and are of no value whatever.

The best exposures are seen on the Brazos river at Calvert Bluff, where three seams of twelve feet, three feet, and three feet, aggregating eighteen feet of brown coal, are exposed near the centre of the bluff. The deposit shown here continues for a distance of nearly a mile up and down the river. The beds of this region are shown in the following section:

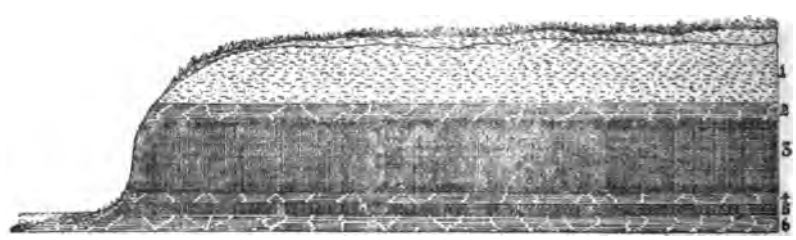


Fig. 10.
Profile of Calvert Bluff.

CALVERT BLUFF SECTION.

1.	Brown loamy clay	4	feet.
2.	Light brown sand	7	feet.
3.	Brown sand and gravel	1½	feet.
4.	Gray sand	0 to 3	feet.
5.	Brown coal	12	feet.
6.	Dark blue clay	3	feet.
7.	Brown coal	3	feet.
8.	Dark blue clay	6	feet.
9.	Brown coal	3 to 4	feet.

Several exposures occur in the banks of the Little Brazos, on the Joseph and Jesse Webb leagues. In this region the most important opening is that on the Dr. George McLendon farm, on the Joseph Webb league, where the coal has a thickness of eight feet, as shown in the following section:

1.	Brown sandy river deposit and soil	10 to 15	feet.
2.	Gravel	2	feet.
3.	Thin bed of brown sandstone containing leaves	1½	feet.
4.	Gray laminated lignitic sand	5	feet.
5.	Brown coal	8	feet.

A similar exposure also occurs on the north side of the Jesse Webb league.

Near the north side of the John Fisher headright a shaft sixty feet deep cuts into the coal deposit six feet.

Throughout the prairie regions the brown coals appear near the surface at various localities, and are exposed in several of the creeks and washouts traversing these regions. At Headville, on the C. C. Seal headright, the exposure is from four feet to six feet thick, and the deposit on Wilson creek is about the same thickness. Many of the surface exposures, however, are thin and of no economic value. Thus the exposure on the Captain Owis farm, on the southwest corner of the George Robertson league, is not more than two feet of broken crumbly coal. Another outcrop or a similar nature occurs in a creek near the centre of the Joseph Fisher league. The coal at this locality is broken and crumbly at the south end, or toward the head of the creek, but as it extends northward it becomes dark brown in color and assumes a woody or peaty structure, having all the characteristic odor of the latter material when freshly broken, and also contains numerous fragments of leaves. The heavier deposits of brown coal found throughout the prairie regions all lie at a depth of forty-five feet and over. A number of borings on the

southwest corner of Beck's prairie, on the Wm. Fullerton league, show section of:

1.	From surface to first brown coal	46 to 55	feet.
2.	Brown coal	4 to 4½	feet.
3.	Parting of sandy clay	10 to 12	feet.
4.	Brown coal	7	feet.
5.	Parting clay and sand	6 to 10	feet.
6.	Brown coal	3	feet.

Brown coal also occurs in the neighborhood of Owensville, where it is overlaid by a red sandstone. This appears to be the last exposure of the brown coal deposits occurring in the southern portion of the county. At Hearne this coal is found at 408 feet, while in the neighborhood of Wheelock, and at places between this place and Franklin Wells, fifty to sixty feet frequently cuts brown coal.

Throughout the valley of the Brazos and in the region lying between the two rivers, brown coal occurs in the well borings generally at a depth of thirty feet to four hundred feet. This is, however, of a poor quality and in no great quantity. A small ledge of brown coal crosses the river near Collier Ferry, and can only be seen at a low stage of the river. This deposit is of no economic value.

Desultory mining and prospect work has been carried on at various times for a number of years throughout this region. A shaft sixty-five feet deep was dug several years ago on John Walker's land, about three miles north of Calvert. Another shaft over 100 feet in depth was dug on Beck's prairie by the Texas Coal Company, and several smaller shafts have also been made in different portions of the county by Mr. W. A. Dollance and others.

Brown coal has been mined and shipped at different times from Calvert Bluff, and a quantity, estimated at three hundred tons, has been obtained from a surface opening at Dr. George McLendon's farm, on the Little Brazos river.

The neglect and abandonment of these operations are due altogether to lack of facilities for transportation. They lie mostly at some distance from the railways traversing the county, and hauling by team is too costly.

CALVERT BLUFF, BROWNCOAL DEPOSIT.

ANALYSIS OF LITTLE BRAZOS BROWN COAL, BY E. T. COX.

Moisture	11.00
Volatile matter	39.50
Fixed carbon	45.00
Ash	4.50
	100.00

ANALYSES OF CALVERT BLUFF BROWN COAL.

The brown coal from Calvert Bluff closely approximates pitch coal. Color black, lustre dull to bright pitchy. Of distinctly lamellar structure and jointed. Shrinkage cracks make an angle of twenty degrees more or less with line of bedding. More friable than the less lamellar varieties examined. Streak fatty, does not soil the fingers. No woody structure observed in the specimens used for analysis.

	Dr. Everhart.	J. H. Herndon.
Moisture	15.86	20.30
Volatile matter	44.89	35.94
Fixed carbon	29.34	31.56
Ash	9.91	12.20
Sulphur	.....	.....
	100.00	100.00

	Thoroughly air-dried	Fresh specimens
Moisture	8.70	16.40
Volatile matter	39.16	41.52
Fixed carbon	40.16	33.42
Ash	10.45	7.70
Sulphur	1.38	.96
Total	100.00	100.00

The deposits at Rockdale and Jones' Prairie, in Milam county, are the direct continuations of the deposits of Lignitic age as described in the counties east, and at the former place the shafts dug show three beds, as elsewhere, but of variable thickness. Thus the thickness of the beds at Rockdale were, in descending order, six and one-half feet, five feet, and the lower one, which was one hundred and thirty-four feet below the surface, was seven and one-half feet, with a parting of ten inches of clay.

Another exposure is at Black Spring, in the northeastern portion of the county, where a bed shows a thickness of two feet above the water line. It has more the appearance of a leaf coal than of the ordinary brown coal.

The geology of the country is decidedly Lignitic in all its features. The surface is generally flat or very slightly rolling, and whenever any slight elevation occurs it is due to the presence of a thin broken deposit of ferruginous sandstone. The railway cuttings in the neighborhood of Rockdale, and between that place and the mines, show a gray or brownish gray and mottled sand, with a ferruginous sandstone covering in places and occasionally pieces of silicified wood of various sizes. The sections shown in the shaft of the mines are practically similar. The section of the Rockdale Mining Company's shaft shows the following:

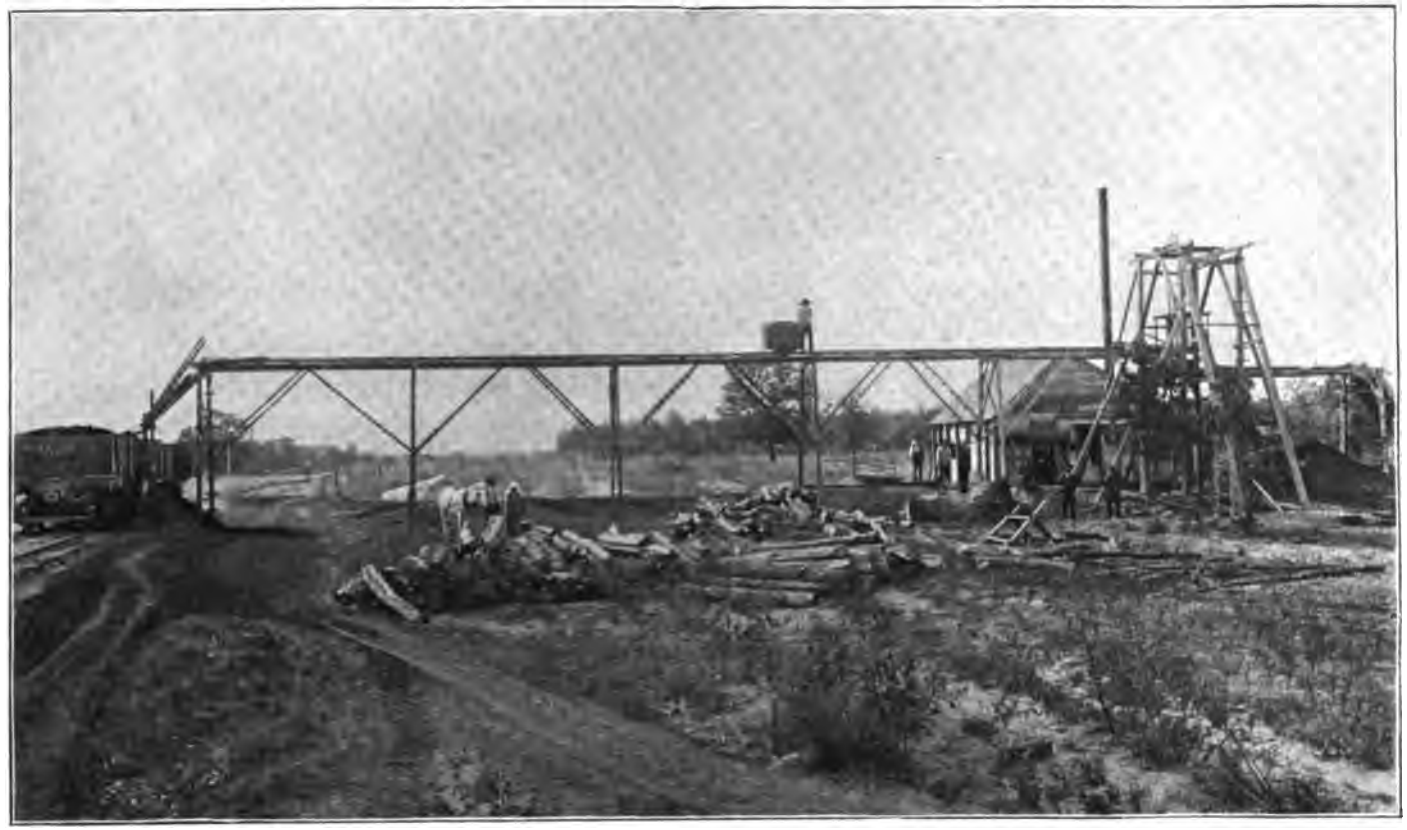
1.	Brownish gray sand	1½	feet.
2.	Red clay	4	feet.
3.	Black waxy clay	4	feet.
4.	Thinly laminated dark gray sand and clay laminæ from one-eighth to one inch, and the clay generally the thicker	15	feet.
5.	Gray clay (soapstone)	12	feet.
6.	Gray sand	1½	feet.
7.	Clay, same as No. 5	8	feet.
8.	Brown coal (first level of mine)	5	feet.
9.	Clay, same as No. 5	8	feet.
10.	Gray sand and clay, same as No. 4	6	feet.
11.	Clay, same as No. 5	8	feet.
12.	Gray sand	1½	feet.
13.	Brown coal (second level of mine)	9	feet 10 inches.

According to Mr. Vogel there should be added to this:

14.	Sand	30	feet.
15.	Brown coal	4	feet.

The wells of the Rockdale Water and Light Company's works are sixty feet deep, and passed through alternate deposits of sand and clay, ending in sand.

Without a complete survey of Milam county it would be impossible to give even an approximate idea of the extent of this field. Brown coal has been found several miles south of Rockdale and northward to the vicinity of Little river. How far west of Rockdale the deposit extends is not known, but it goes eastward for several miles. Mr. Vogel claims that he has six hundred acres underlaid by a five foot deposit, on the Gulf, Colorado and Santa Fe railroad, four miles north of Milano Junc-



VOGEL MINE, MILAM COUNTY.

tion, and this field can doubtless be connected directly with the brown coal deposits of the Calvert Bluff region, as brown coal occurs on the Milam side of the Brazos two miles north of Calvert Bluff.

The mines* are situated three miles east of Rockdale and close to the line of the International and Great Northern Railway, with which they are connected by short sidings.

They are also comparatively close together, the distance between the two shafts being only five hundred or six hundred yards, and both are almost within sight of the abandoned workings of an old mine belonging to the Austin Consolidated Mining Company.

The Rockdale Mining and Manufacturing Company is an incorporated company, having a capital of $60,000. They have five hundred acres of land, hoisting gear, fifteen-horse power engine and twenty-horse power boiler, cars, etc., and have done considerable work in opening up and developing the mine.

The mine itself is entered by a shaft six by eight feet in section and sixty-six feet deep. The shaft is closely timbered and divided by a series of beams into two compartments, one five feet, devoted to the hoisting machinery, and the other three feet, being left for ladders and pumping machinery should it be found necessary at any time to place pumps in the mine. At present pumping is not required and the space is left open for ventilation.

At a depth of forty-two and one-half feet the floor of the first level is reached. This is in the first deposit of brown coal. The entry is driven north about fifty and south about eighty-seven feet, and has a section eight feet in width and an average height of about four feet. Going north, at twenty feet from the shaft, the first room is turned east and shows an area of twenty-five feet square. Sixteen feet further north, another room of the same size has also been turned east. Nine-foot pillars are left between the gallery and the rooms. Opposite room two an entry has been driven west a distance of twenty-five feet.

Going south from the shaft the gallery extends eighty-seven feet, from which three entries have been made. No. 1 opens from the gallery thirty feet south of the shaft and extends sixty feet southwest to the air shaft. From this another entry has been begun and carried north thirty feet. It is intended to continue this northward so as to connect with the entry

*The descriptions of this and other mines are from notes of W. Kennedy.

turning west at the north end of the north gallery, so as to facilitate the ventilation of that portion of the mine. Twelve feet south of the road leading to the air shaft, another entry going east, thirty feet long has been made, and twenty feet still further south the third opening of twelve feet has been made, turning in a southwesterly direction.

The floor of this deposit is not level, and at one or two places in the neighborhood of the air shaft as much as two feet of the underlying clay has been removed in order to give room for working, the deposit having pinched that much, showing a section like that in Plate XXIII.

This upper deposit has been abandoned for the present. The northern end already abuts close upon the railway property, and the south shows a deepening with the dip of the beds, which is here very slight and in a direction south of east.

The second bed of brown coal has been cut through and galleries extending north and south opened, and at the date of my visit had reached the proportions shown in Plate XXIII.

In both of these levels the roofs are bad and the timbering has to be very close. One foot of the upper deposit is left to form a roof and props are placed at intervals of four feet. Cross-beams are placed on the top of each pair of props. Poles are also placed longitudinally throughout the galleries and rooms as additional protection.

In the lower level seven feet of the brown coal is taken out and the rest is left as a covering. The system of timbering is also the same as in the upper level.

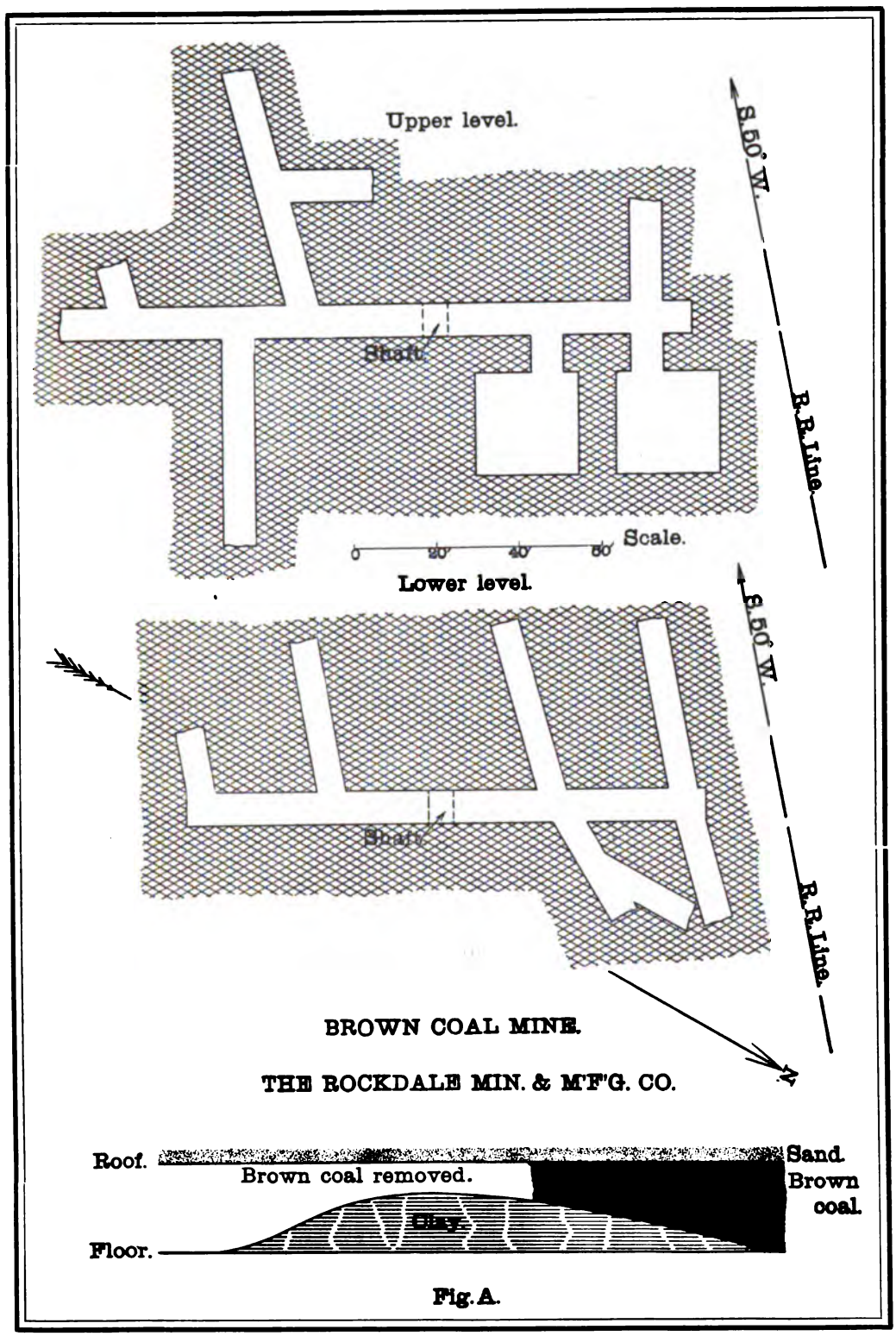
The hoisting gear of this mine is worked by steam with a fifteen-horse power engine driven by a twenty-horse power boiler. The cage is four feet square, and lifts a car containing one-third of a ton of coal.

In raising and loading the coal into the cars, the cage with its load is lifted twenty-six feet above the mouth of the mine and the loaded mine car is carried along a platform thirty-feet in length and emptied into a chute with a grated bottom, down which the coal runs into the railway cars. The grating of the chute forms a screen through which the dust and small coal falls.

The mine employs at present thirteen men—nine miners, and the others above ground.

The brown coal from this mine is shipped to Waco, Temple, Taylor, and other points, and is used by the Rockdale Water and Light Company.

PLATE XXIII.



BROWN COAL MINE.

THE ROCKDALE MIN. & M'F'G. CO.

Fig. A.

This company uses the brown coal in connection with wood in the proportion of half brown coal and half wood, and say it gives better satisfaction than all brown coal or all wood, under the existing system of grates.

The brown coal occurs in the mine in a much broken condition, and frequent vertical seams of a slaty grade of brown coal or indurated lignitic sand with thin seams of pyrites occur. These vertical seams usually have a thickness of two to four inches, occasionally thickening to six inches.

In the Herman Vogel mine the brown coal is reached by a shaft sixty-two feet deep. The coal is obtained altogether from the upper deposit at a depth of thirty-two feet. The coal in this seam is from four to six feet thick, with a sandy roof, and the gangway and all workings have to be timbered very closely. No settled method of working appears to be carried on. As a rule, the galleries have been run to the line of the property and then the workings carried back toward the shaft, allowing the roof to come down when all the brown coal has been obtained. The working portion of the mine is kept open by propping every four feet.

No brown coal is obtained from the second or lower deposit in this mine on account of water, no arrangements having been made for pumping. At present this deposit is twelve feet under water.

The hoisting gear, including engine and boiler, is the same as that at the Rockdale mine. The loading facilities are also the same, with the exception of the platform, which is much longer, being nearly three hundred feet. Six men are employed, and the price of mining is the same as at the Rockdale mine. The coal is shipped mostly to Taylor.

The brown coal from this mine is lighter in color and more woody in structure than that obtained from the lower deposit at the Rockdale mine, but in most respects is similar to that taken from level No. 1 of that mine.

The Rockdale brown coal is a pitch coal, black in color, has a fatty streak, lustre dull to pitchy, smeary, containing some streaks of earthy material. Shrinkage cracks not always so nearly perpendicular to lamellar structure as in some other varieties, resembling the Calvert Bluff variety in this respect. Fracture somewhat splintering. No traces of wood structure observed.

The following analyses give the proximate composition of different specimens from these beds:

	Ross.	Ross.	Ross. Air-dried.	Freshly mined. Rockdale M. & M. Co.	Freshly mined. Vogel.
Moisture	19.925	13.80	9.75	18.25	17.75
Volatile matter	52.425	43.55	40.65	36.73	37.85
Fixed carbon	22.000	36.83	38.80	37.28	37.40
Ash	5.650	5.82	9.60	7.00	6.20
Sulphur	1.235	1.35	1.20	0.74	0.80

There is an outcrop of brown coal in Lee county on Rabb's creek, in the southern portion of the county, about 400 yards below the San Antonio and Aransas Pass Railroad crossing. This bed is twenty inches thick, overlaid with a yellow clay, and is (apparently) of good quality.

At Giddings, in Mr. F. Raube's well, a bed of brown coal six feet thick was found at a depth of eighty feet, and another seam of four feet at a depth of 120 feet.

At Blue Branch, in the western portion of the county, there is a six-foot seam of brown coal, which has been prospected and is being tested for commercial purposes. The coal is a pitch coal, massive to laminated in structure, of semi-conchoidal fracture, and contains some lignite An analysis shows:

Moisture	,16.50
Volatile matter	36.07
Fixed carbon	37.17
Ash	'8.60
Sulphur	1.66

The first discovery of brown coal in Bastrop county was in 1837, by Mr. Jas. Nicholson and Judge Pinckney Hill. Since that date it has been found in many parts of the county in beds of greater or less thickness.

Exposures on Cedar creek, four miles west of Bastrop, show the brown coal to have a thickness of ten feet and over, but it is sometimes parted by seams of shale containing a considerable amount of iron pyrites. Some of the material has been mined for local consumption.

On the Colorado river, one mile and a quarter below the mouth of Sandy creek, a bed of woody lignite five feet in thickness is exposed along the river bank for some distance, and one hundred yards further down is found a bed reaching from water level to six feet above. This latter bed shows some jointing.

Two miles above Bastrop another bed was observed just at the water

level, and half a mile further down a bluff showed two beds, the upper one three feet in thickness and the lower one five feet; the two being separated by fifteen feet of gray sands and blackish-gray clays.

Seven miles below Bastrop is a lenticular bed of brown coal, which is eight feet in thickness along an exposure of one hundred and fifty feet, and a mile below an earthy friable brown coal bed three feet thick is found, associated with interlaminated gray sands and chocolate clays. From this point the brown coal beds were not observed again until we passed Smithville, one mile below which we found the last exposure seen in Bastrop county. It was underlaid and overlaid by laminated chocolate sands.

Brown coal is also reported as occurring in the vicinity of Paige.

The only mine which is being worked in Bastrop county at the present time is located three and one-half miles from the town of McDade on Martin's Hollow creek, Joseph Black headright, near the line of the Houston and Texas Central Railway.

The owner, Mr. W. B. Mowatt, of San Antonio, furnishes the following information regarding it: He has sunk an eight foot shaft fifty-five feet in depth. At twenty-seven feet he found the first seam of brown coal, which has a thickness of eight feet. It is overlaid by sandstone and underlaid by a clay bed which is seventeen feet thick and forms the roof of the second coal seam. The lower seam has been dug into to a depth of five feet, but has not been cut through. The mining, which has just been started, will be by chambers. Two galleries have been cut, one forty and the other fifty feet in length, and one chamber opened. In addition to the sandstone, which is probably firm enough to form a good roof, a part of the coal is left for covering.

The mining machinery consists of a fifty-horse power boiler, hoisting engine, etc., and the capacity of the mine can be increased to meet any demands. A few carloads have already been shipped to Austin and San Antonio, and it is in use at the ice factory at the former place and is giving satisfaction.

The coal is a good quality of brown coal, with pitchy streaks, cubical fracture, and passing into pitch coal in places. No traces of wood structure in any specimens which have been submitted to the Survey.

Brown coal is found in the vicinity of Prairie Lea, Caldwell county. It occurs in many places in the eastern portion of the county, and was

found in boring wells at Luling. It also crops out on the Sandy Fork of Peach creek, just at edge of the water, and well sections in the neighborhood of Pin Oak creek show three beds, varying from one and one-half to two feet in thickness.

At Burdett's Wells numerous outcroppings are found in the neighboring creeks and ravines.

Specimens sent in by Mr. S. J. McDowell show two varieties of coal. The first is a glance coal, which from its fragmental condition would appear to occur only in small quantities. The other is a brown coal of good appearance, some of it massive and the remainder laminated, and both showing some traces of woody structure. The specimens are from the Burdett Wells exposures.

ANALYSES.

	Glance coal.	Brown coal.
Moisture	13.06	8.15
Volatile matter	43.18	29.06
Fixed carbon	36.59	39.73
Ash	7.17	23.08
Sulphur	5.70	1.33

In Atascosa county, near Somerset, we have two brown coal mines that were in operation several years. The brown coal bed of the Kirkwood mine, which is reached by a tap road from the International and Great Northern Railroad, about eighteen miles southwest of San Antonio, was first discovered in a well on the Harrison place, and was subsequently opened out and operated by Mr. Kirkwood, a mining engineer from Scotland. The roof is a friable sandstone, and the coal is five feet three to six inches thick, and has met with much acceptance in San Antonio as a fuel. The chief objection to the brown coal is the liability to disintegrate in handling, which makes the coal small and unsuited to burn in an ordinary grate or stove. Close set fire bars have been in many cases adopted, which obviates the objection, and in other respects it is a good and cheap fuel.

The Kinny mine, which is on the adjoining property, is in all respects the same as the Kirkwood, and need not be described. In well digging at a number of points the coal is struck at more or less depth from the surface, and doubtless as the demand increases shafts will be sunk, especially near the International and the Southern Pacific railroads, both of which pass through that section.

Analysis of specimen of brown coal from this bed gives:

Moisture	13.285
Volatile matter	59.865
Fixed carbon	18.525
Ash	8.325
	100.00

In the southern part of Medina county we come upon the boundary of a large area, consisting of a series of shallow depressions or basins, possibly of lacustrine origin, in which the brown coals of that section abound. This area embraces all of Atascosa county, the western part of Bexar, and the northern portion of Frio county. It extends west and southwest also, as has been already stated, to the Rio Grande. In going down upon these deposits or beds of brown coal we find that they thin out and again recur in certain definite areas of depression, generally more or less circular in form. Near Lytle we have the best development of the brown coal of the county in a mine which has been opened on the lands of Mr. John T. Lytle, a short distance from the International Railroad. The top of the seam is reached by a shaft sixty feet deep. A section downwards of the superincumbent strata consists of three feet ferruginous sand, fifty-three feet of clay, the lower part of which assumes a jointed form, and the roof is sandstone. The coal bed is five feet thick, sometimes increasing a few inches, and lies nearly horizontal on a bed of fire clay twelve inches thick. The quality of the brown coal is fairly good, but is occasionally mixed with thin bands of shale containing iron pyrites. The coal is readily saleable in San Antonio, and as the wood supply is curtailed, the demand will be shortly very considerable.

The Lytle mine is situated in the northeastern section of Medina county, close to the Atascosa county line. The mine is within one mile of Lytle Station on the International and Great Northern Railway, with which it is connected by a siding a little short of half a mile in length.

The country in which this mine is situated is flat and covered throughout the region by a gray or brownish gray sand, containing boulders of a bluish gray sandstone altered to brown on the outside. The section shown at the mine is:

1.	Brown sand with boulders of sandstone	10 feet.
2.	Yellow laminated clay with occasional pebbles and small boulders	10 feet.
3.	Laminated yellowish gray sand with black clay or lignitic partings, indurated in places, very friable and easily disturbed, frequently falling from the roof of the mine and caving badly...	12 feet.

4. Brown coal, with lignite..... 5 to 7 feet.
5. Gray clay, floor of mine.

The general dip of these beds is toward the southwest at a very slight angle.

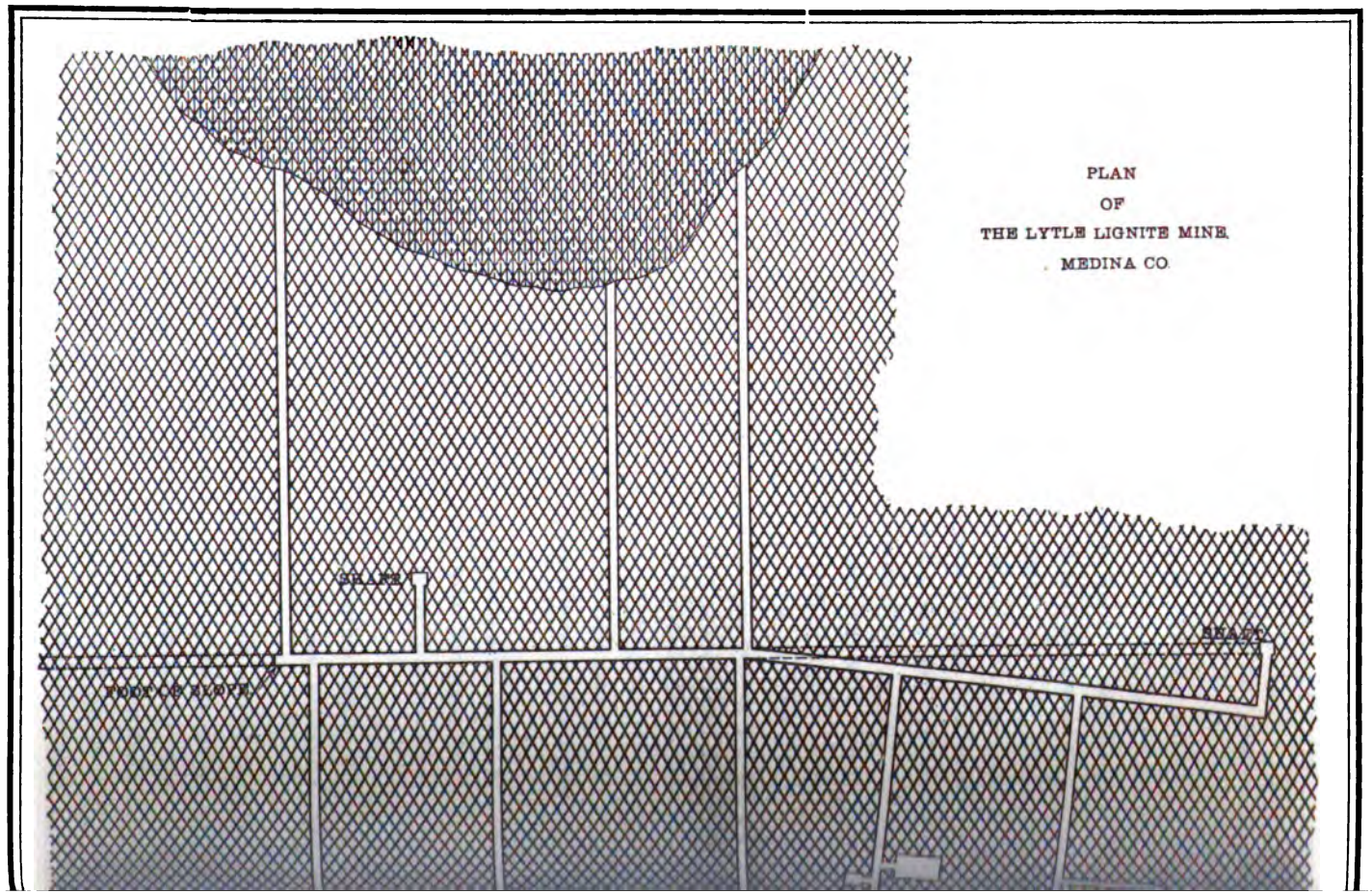
The mine itself is entered by a slope running north 39° west with a pitch of one in ten, and is seven hundred feet long. The main gangway extends from the foot of the slope north 39° west three hundred and sixty feet, after which it changes slightly toward the east and continues to a distance of four hundred and thirty feet to an air shaft.

Beginning at the foot of the slope there is a series of old workings now abandoned. These workings consist of three drifts on the east and four on the west side of the gangway. Those on the east are respectively six hundred, six hundred, and three hundred feet in length. The two six hundred feet drifts are one hundred and fifty feet apart, and the three hundred feet drift two hundred feet farther north. The brown coal in these has been practically worked out. On the west side, the drift nearest the foot of the slope is four hundred feet, two hundred feet north the next is three hundred feet, and one hundred feet farther north the next is four hundred feet long, and the fourth drift, one hundred feet north of this, is four hundred and fifty feet in length. These four drifts all end at the water line—that is, it will not be possible to obtain any more coal there without a system of continuous and consequently somewhat expensive pumping.

The new workings of the mine consist of two drifts, each nine hundred feet in length, running in a northeasterly course from the gangway. These are one hundred and fifty feet apart, the first being four hundred and eighty feet from the slope. Plate XXV.

The present gangway and workings show a cross-section eight feet in width and averaging four feet in height. The rooms are generally small.

This mine is ventilated by an air shaft situated in the north end of the gangway. The fresh air enters the slope and passing along the gangway to the first drift of the new workings. The gangway is here closed by a door and the air current deflected through the nine hundred feet drift. A cut there admits the air to the upper end of the second drift, through which it passes into the upper end of the gangway, and thence escapes through the air shaft.


PLAN
OF
THE LYTLE LIGNITE MINE
MEDINA CO.
SHAFT
SHAFT
FOOT OF SLOPE

PL

XXV.

WORKABLE LIGNITE.
LIGNITE CHARGED WITH WATER.
0 50 100 200 300 SCALE.

The roof of this mine is decidedly bad, and very close timbering is required. One foot of the coal is left to support the overlying sand, and props with cross-timbers are set up every four feet, yet caves are of very frequent occurrence.

There is also some danger from the occurrence of choke damp—particularly in the vicinity of the old workings.

The hoisting machinery of this mine is run by a fifteen-horse power engine driven by a fifty-horse power boiler. The loaded cars, holding about a third of a ton of coal each, are hauled to the foot of the slope by a mule, and from that point the coal is hoisted to the surface and up to the top of a platform thirty feet in height. From this platform it is run down a chute having a double screen bottom. The coarser pieces of coal pass over the upper screen into the railway car, while the finer particles, stopped by the second screen, are returned to the engine house, where they are used for fuel. Nothing but very fine dust passes the second screen. This last material is considered of no use, and is thrown on the dump. The quantity of dust thus taken out is very small, amounting to about one ton to every thirty-five tons of coal.

About thirty-two men are engaged at this mine, twenty of whom are miners and the rest laborers. It is worked mostly by Mexican labor.

The output is two car loads, or a little over forty tons, daily. It is shipped to and sold altogether in San Antonio.

The mine has been in operation for a period of over twelve years, during the last six of which it has been controlled and operated by Mr. J. S. Carr, of San Antonio.

A proximate analysis of this coal yielded:

Moisture	13.25
Volatile matter	40.62
Fixed carbon	36.47
Ash	8.40
Sulphur	1.26
Total	100.00

In Frio county coal occurs on the San Miguel river, fifty miles south of San Antonio. From this locality it was hauled to San Antonio many years ago, and there employed by the blacksmiths, who pronounced it of moderately fair quality. By a gentleman engaged in working the seams Dr. G. G. Shumard was furnished with the following section of this locality:

1. Soft bluish-black bituminous shale.
2. Brown coal, 2 feet thick.
3. Shale of the same character as above.
4. Brown coal, 18 inches thick.
5. Shale.
6. Brown coal, 20 inches thick.

These are both underlaid and overlaid by sandstone.

Fourteen miles southwest of Uvalde is found the northwestern exposure of the Nueces or San Tomas coal fields. The outcrop in the edge of the water of the Nueces river was found to be four feet thick, with a two and one-half inch division of shale in the center. Mr. Gillespie, upon whose land the outcrop occurs, states that he sunk a shaft into the coal, and found it to be an excellent quality, and to be four feet ten inches thick, with a two-inch division in the center. This is the same coal that is being worked at San Tomas, but its area in Uvalde county is very limited and will only be found near the county line joining Zavalla. Above this coal is a stratum of four feet of argillaceous shale; then three feet of ferruginous sandstone. Below the coal there are eight inches of fire clay, fourteen feet of yellow and gray sandstone of a soft friable character; then several feet of shale, under which there is a bed of oyster shells which has a thickness of twelve feet. This oyster bed is underlaid by eight feet of black asphaltum sandstone, from which in warm weather the asphaltum exudes and forms small pools.

On the Nueces river, ten miles west of Fort Inge, a seam of bituminous coal several feet in thickness has been discovered. The coal has been employed by the blacksmiths at the Fort, and found to be of good quality. This deposit is probably Cretaceous.*

A line drawn from the point where the Zavalla and Uvalde county line crosses the Nueces river, to the south line of the Francisco Perera survey, will represent the western limit of the Nueces coal field in Zavalla county, thus leaving about two-thirds of the county in the bounds of the coal field. The rocks in this county dip to the southeast from a few miles west of the western limit of the coal field.

All of the western half of Webb county is in the limits of the Nueces coal fields. There are three strata present in a part of the county, but the middle is the only one of any economical value. This stratum

* G. G. Shumard. This may be a reference to the same locality as that above, and there is a possibility that the bed described may belong to the same series as that at Eagle Pass.

ranges from eighteen to thirty-three inches in thickness, and has a two-inch division of slate in the center. It is a very firm, solid coal, and breaks with a glossy, conchoidal fracture, and is not easily pulverized. It is very clean and free from dust, and has the appearance of hardened asphaltum. It contains but few plant impressions, is remarkably free from sulphide of iron, burns with a vigorous bright flame and oily appearance, contains a considerable quantity of ash, but will not make clinkers if separated from the slate in the center of the stratum. It has some of the characteristics, but not the slaty cleavage, of cannel coal.

The most northern exposure of this coal observed in Webb county was about twenty-five miles northwest of San Tomas, where a seam of pitch coal was found which was black, massive, dense, and so firm that it does not give a greasy streak with finger nail. No trace of wood structure, sub-conchoidal fracture.

About eight miles west of San Tomas, at Espada creek, we find three seams of brown coal.

The upper seam is twelve inches thick, and is a massive pitch coal with conchoidal fracture, very similar to the body of the San Tomas coal. It is underlaid by four feet of shale, and this by the San Tomas seam of coal, which is here thirty-four inches thick with a two-inch division of slate. This coal is underlaid by thirty feet of shale, below which is a third seam of brown coal, varying in color from light to dark brown, with many traces of woody structure, impressions of leaves, etc.

San Tomas is the only place where coal is mined on any considerable scale south of Eagle Pass. The coal bed is two and a half feet thick, and separated by a two inch seam of hard black clay in the middle. The coal is jet black, highly glossy, and has a conchoidal fracture. It is generally massive, though it sometimes has the structure of bituminous coal.

This material has proved a very serviceable fuel, and is especially valuable in a country like Southern Texas, where there is no other coal, and where wood is very scarce. A railroad, the "Rio Grande and Pecos," runs from the mine to Laredo, a distance of twenty miles, thus facilitating the shipment of the coal to the various markets. It is extensively used on the Mexican International Railroad, and for steam and household purposes in Laredo, and has already become an important factor in the welfare of the region. When the mine was visited in May, 1889, the output was 100 tons a day.

The following section shows the occurrence of the coal:

1. Calcareous sands.....12 feet.
2. Friable sandstone.....12 feet.
3. Chocolate, gray, white, and brown clays, with sulphur and gypsum crystals in layers, running downward into black clays, with a two inch seam of lignite a few inches above 4..10 feet.
4. Brown coal of the variety pitch coal, massive, black, and glossy, with conchoidal fracture in places, but having the form of glance coal and structure of bituminous coal in others ..... 1 foot 3 inches.
5. Hard black clay..... 2 inches.
6. Brown coal, same as 4..... 1 foot 3 inches.
7. Gray clays containing thin seams of lignite in the portion directly underlying 6.....10 feet.

The entrance to the mine is on the river bank, forty-seven feet above the water level. The dip of the coal seam is at this place about two degrees. The roof is the black lignitic clay.

Analysis of specimens collected by J. Owen gave the following results:

Pitch coal from outcrop twenty-five miles northwest of San Tomas, thoroughly air dried.

Moisture	2.35
Volatile matter	42.67
Fixed carbon	37.57
Ash	16.55
Sulphur	.86
	100.00

Analysis of specimen from the San Tomas coal mine:

Moisture	2.59
Volatile matter	51.05
Fixed carbon	39.01
Ash	7.35
Sulphur	1.50
	100.00

CHAPTER VIII.

OCCURRENCE AND COMPOSITION OF THE BROWN COALS OF THE TERTIARY—continued.

The second series of brown coal beds are connected with those deposits of Claiborne age, which embrace portions of Harrison, Gregg, Smith, Cherokee, Anderson, Houston, Nacogdoches, San Augustine, Sabine, Freestone, Leon, Robertson, Brazos, Burleson, Lee, Bastrop, Gonzales, Wilson counties, and all of Shelby, Panola, and Rusk, so far as yet determined. Some of these deposits have already been described in connection with those of the Lignitic. They are usually in thinner deposits than the beds of the Lignitic, but in places they are of very good quality, and occur in beds of sufficient thickness for exploitation.

In Panola county there is a large deposit of brown coal, the bed apparently varying in thickness in different localities.

At Grand Bluff it was seen cropping out at the water line of the Sabine river, near the ferry, and in places it forms the bed of the river. This is a brown coal, with some pitch coal, and is of highly laminated structure.

On the Allison tract, six miles east of Tatum Station, it crops out at the base of a hill on a little stream fed by springs, which flow from the water-bearing sand in contact with and overlying the brown coal.

About four miles south of Carthage, on the M. Payne headright, Baker's subdivision, were seen specimens from a prospect hole then full of water. The bed was reported to be two feet thick.

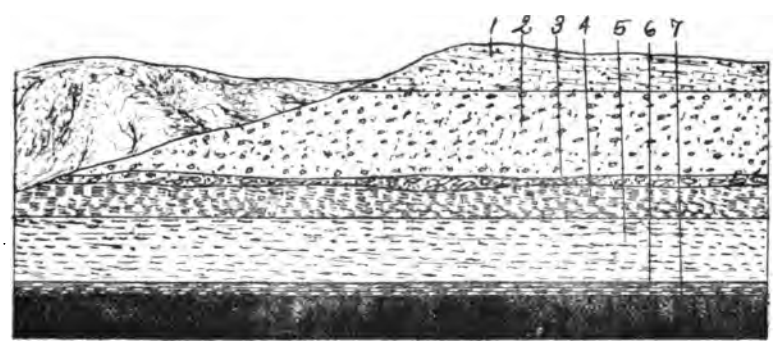


Fig. 11.

SECTION FOUR MILES SOUTHEAST OF CARTHAGE.

1. Sandy soil in cultivated field..... 2 feet.
2. Drift in pockets, iron gravel, and magnetic pebbles..... 4 feet.
3. Ochreous centres of iron geodes broken by cultivation.. 1 to 6 inches.
4. Red and mottled red and gray clay..... 18 inches to 2 feet.
5. Gray clay—plastic, but slightly sandy..... 3 feet.
6. Lignitic clay shale, with plant fossils—very friable ... 8 inches.
7. Pitch coal, sub-conchoidal, some lamellar structure..... 2 feet.

The best exposure was seen at Mineral Spring Ridge, four miles northwest of Beckville, where a tunnel had been excavated nearly north and south one hundred and fifty feet in the bed of brown coal, which is here four and one-half feet thick. Several car loads of this brown coal had been shipped to Longview, where it was burned in grates for domestic purposes. It was also tried in the fire box of a wood burning locomotive on the Texas, Sabine Valley and Northwestern Railway with some success. The two obstacles to its continued use were:

First. The exhaust steam discharged into the fire box from the cylinders disturbed the arrangement of the coal.

Second. The cheapness of wood, $1.75 per cord to the road, left no inducement to change the construction of the furnaces in the engines.

This brown coal is typical of the formation in Panola county. It is a brown coal of distinctly laminated structure, passing in places into pitch coal, and containing slight traces of lignitic matter. A specimen taken from the end of the tunnel shows the following composition on analysis:

Water	20.80
Volatile matter	52.08
Fixed carbon	22.67
Ash	3.97
Sulphur	0.48
Total	100.00

About seven miles south of Timpson, in Shelby county, in the northeastern portion of the W. J. Crump headright, at the falls of a small stream tributary to the Attoyac creek, in a gully about eleven feet deep, was seen a bed of brown coal apparently four or five feet thick. It formed the bed of the gully and was similar to the brown coal bed of Panola county.

The little stream has cut through a considerable portion of the bed. The peculiarity of this bed, partly exposed, is the exhibition of numerous parallel fault lines, running east by north and west by south, indicating

great lateral pressure from the direction north by west, with an apparent slight upward sliding. The exposure is unequal in the two banks of the stream. In the bank on the eastern side it is covered by about two feet of soil. On the western side it is covered by about six feet of valley drift. The difference is probably the result of a previous erosion of the brown coal bed, before the deposition of the valley drift.

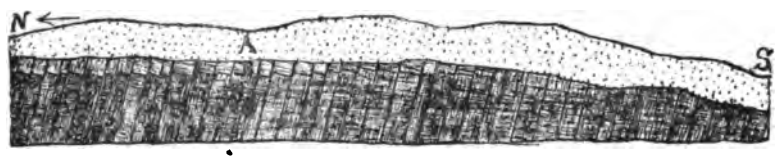


Fig. 12.

FAULTED BROWN COAL BED, SHELBY COUNTY.

A. Sandy soil..... 2 feet.
B. Lignitic shale..... 1 foot.
C. Brown coal..... 4 feet.

No other exposures of the brown coal bed were observed in this county, but it is probable that it is of considerable extent.

An analysis of a specimen of this coal from the outcropping shows the following composition:

Moisture	18.26
Volatile matter	43.51
Fixed carbon	29.53
Ash	8.70
Sulphur	2.46

Similar brown coal is also reported from the northern portion of Nacogdoches county, between Garrison and Linn Flat.

Our detailed examinations in Rusk show that a large portion or this county is underlaid by deposits of brown coal, exposures of which occur at a great many localities. The beds examined vary from six inches to eight feet in thickness, and are associated with bituminous shale, fire and potter's clay, soft quartzose, and argillaceous sandstone, impure limestone and iron ore. At a number of localities visited the brown coal appears to be of good quality and adapted for the ordinary purposes of fuel. It varies greatly in character in different sections of the county, some specimens exhibiting the woody fibre with tolerable distinctness, while others show no traces of organic structure, being dull, shining black, and very compact in texture.*

* Shumard's First Report of Progress.

Dr. Riddell's analysis of a specimen from neighborhood of Iron Mountain gave:

Moisture	15.701
Volatile matter	4.105
Fixed carbon	79.137
Ash	1.057
Total	100.00

At or near Sulphur Spring no exposure of the brown coal bed was observed, but the siliceous limestone above it, as well as the remarkable development of micaceous sandy lignitic clay shale in a little branch just west of Sulphur Spring church, would indicate its presence below. The running water in this branch, as well as a similar one just east of the church, has cut ravines in this material several feet deep. At Sulphur Spring is a fault exhibiting a portion of this lignitic deposit.

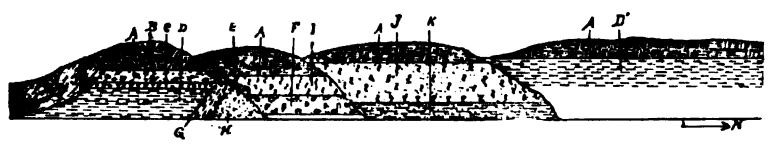


Fig. 13.

SECTION AT SULPHUR SPRING, RUSK COUNTY.

A.	Reddish soil	5 feet.
B.	Pebbles, drift	2 feet.
C.	Clay	1 foot.
D.	Micaceous sandy shale (lignitic series).	
E.	Conglomerate bowlders.	
G.	Fault in sandy shale.	
H.	Hard gray sand.	
I.	Clay	4 feet.
F.	Pebbles	4 feet.
J.	Yellow sandy clay	8 feet.
K.	Hard gray sand, with crusts of ferruginous shale, to bed of creek	5 feet.
D.	Lignitic micaceous sandy shale to bed of branch near church or school house	5 feet.

About five miles northeast of Henderson, in Martin's creek, there is a bed of brown coal which is exposed three feet—base not seen. This coal is quite compact. The same bed was found in digging a well south of Henderson, where some six feet of coal is reported.

Brown coal is found also near the school house at Millville.

At Graham's Lake, twelve miles west of Henderson, in the hillside, some twenty feet above the water, there is a bed of lignitic brown coal,

varying in color from brown to brownish black, friable, and of slightly laminated structure.

A sample of this brown coal exhibited the following composition:

Moisture	16.55
Volatile matter	43.90
Fixed carbon	25.40
Sulphur	0.08
Ash	14.15
	100.08

Another specimen from this county, furnished by Mr. E. T. Bostick, is of brownish black color. It is massive and compact in structure and shows no traces of woody fibre; fatty streak under finger nail. Fracture uneven, sometimes subconchoidal. Shrinkage cracks irregular. Lustre dull to pitchy. Small particles of resin occur in the coal, which is so firm that it does not soil the fingers.

The following analyses have been made of it:

	Fresh Coal.	Air-dried.
Moisture	16.825	7.15
Volatile matter	46.325	45.86
Fixed carbon	31.475	40.56
Ash	5.375	4.95
Sulphur	1.09	1.48
	100.000	100.00

In a little branch tributary to Bean's creek, in Cherokee county, three miles north by west of the town of Rusk, E. M. Priest's tract, in the John M. Furgison headright, was seen an outcrop of brown coal underlying a twelve-inch stratum of lignitic clay shale. Overlying the clay shale is six feet of soil drift, including small nodules and fragments derived from the iron series which caps the ridges. Along the same branch are tumbled bowlders of iron conglomerate, or breccia, consisting of cemented angular fragments of iron sandstone and aluminous iron ore, with a few small rounded iron pebbles from the older disintegrated iron pebble conglomerate.

A sample of the brown coal from this locality, submitted to analysis, afforded the following composition:

Water	9.12
Volatile matter	30.32
Fixed carbon	34.22
Ash	22.98
Sulphur	3.36

Brown coal outcrops in several other localities in this county which were not visited, but the character of the coal, as it belongs to the same deposition, is probably similar.

The following specimens of brown coal, submitted to analysis for this report, were collected by Dr. R. A. F. Penrose, Jr.:

ANALYSES OF BROWN COALS.

No.	Moisture.	Volatile. Matter.	Fixed Carbon.	Ash.	Total.	Sulphur.
1109	7.00	53.70	32.55	6.75	100.00	0.89
1110	4.40	34.65	27.70	33.25	100.00	1.33
1111	8.15	43.55	42.50	5.80	100.00	3.37

Localities.

No. 1109. Six miles south of Alto. Brown coal, light to dark brown in color, laminated, subconchoidal in fracture.

No. 1110. Near Jacksonville. Brown coal passing into pitch coal, laminated structure.

No. 1111. McBee's School House, Cherokee county. Brown coal, slightly lignitic. Black to brownish black, with traces of woody structure in places. Fracture even, lustre dull, compact, firm, with traces of decomposed pyrites.

Brown coal is also found at many places south of Alto. Dr. Everhart has published the following analysis of coal from this region:

Moisture	16.42
Volatile matter	18.80
Fixed carbon	28.75
Ash	36.03
	100.00

Sulphur not determined.

The following section, taken three miles north of Rusk, shows the relation of these strata:

1.	Gray and buff sands	8	feet.
2.	Hard brown sandstone	1 to 3	inches.
3.	Brown resinous laminated hematite	1 to 3	feet.
4.	Altered fossiliferous greensand	30	feet.
5.	Gray clay, stained by iron in places	5	feet.
6.	Dark gray sand, with glauconite specks and rusty pyrites, giving rise to many ferruginous springs	20	feet.
7.	Gray and chocolate clays, ferruginous in places	35	feet.
8.	Interbedded seams of gray and chocolate clay and fossiliferous glauconite marl, sometimes indurated and partly altered; nodules and lenses of clay ironstone	40	feet.
9.	Gray clay, with seams of sand, and some clay ironstone	5	feet.
10.	Interstratified gray and chocolate clay	5	feet.

11.	Brown coal	1 foot.
12.	Chocolate clay	1 to 1½ feet.
13.	Brown coal	1 foot.
14.	Chocolate clay	6 feet.
15.	Interbedded chocolate clay and small seams of lignite. ⅛ to ½ inch thick, at base of section.	

The greensand bed near the top of the section is probably the representative of the Smithville bed on the Colorado.

At McBee's School House spring a section shows:

1.	Gray sand	20 feet.
2.	Thin deposit of laminated iron ore	1 foot.
3.	Iron pyrites in black sand	2 inches.
4.	Brown coal	.....
5.	Black clay	4 feet.
6.	Greensand	40 feet.

Brown coal in rather thin seams occurs near Douglas and Fosterville, in Anderson county, and in small quantities on Mr. Butler's farm, northwest of Palestine, very near the Cretaceous-Tertiary contact. The quality of some of these brown coals appears to be excellent, but no detailed examination has been made of them.

A specimen received from Messrs. W. D. Cleveland & Co. was common brown coal. It was taken from an outcrop on Caddo creek about seventeen miles northeast of Palestine. The specimen was gotten from the Alfred Benge survey, where the seam is about two feet in thickness.

The coal is dull black on freshly broken surface, brownish-black elsewhere. Lamellar, some of the laminæ with pitchy lustre, others dull. Slightly smeary. Traces of wood structure in the form of remains of twigs or small branches, but seemingly entirely altered and not in lignitized condition. Fracture even.

ANALYSIS:

Moisture	8.35
Volatile matter	41.28
Fixed carbon	42.73
Ash	6.40
Sulphur	1.24
	100.00

The deposits of brown coal observed along the Brazos river in Burleson county were for the most part too thin to be of much economic importance. A bed two feet thick occurs at Burleson shell bluff two miles

below the county line, and other thin seams are found between this point and Moseley's, or San Antonio ferry. A mile below the mouth of the Little Brazos brown coal beds eighteen inches thick are found, and similar deposits occur to the Washington county line in connection with beds of light green and chocolate clays. They are also known at Deanville, and on Spring creek and Cedar creek. We have had no specimens of these coals for analysis.

The other deposits of brown coal occur in the clays and sands which have heretofore been designated the Fayette division, but are now separated into the Yegua or lower and Fayette or upper divisions. Here again we have very heavy beds, ranging from six to fifteen feet, but seemingly more local than those connected with the lower deposits. This belt has a width of ten to forty miles, comprising parts of the counties of Sabine, Newton, San Augustine, Angelina, Trinity, Houston, Madison, Grimes, Brazos, Burleson, Lee, Fayette, Gonzales, etc. None of these deposits have been opened to the same extent as those of the Lignitic division, and the investigations of the Survey have not as yet covered much of the country in which they are located; for these reasons they can not at this time receive the full description which I would like to give them.

The deposits of Sabine, San Augustine, Newton, and Jasper counties have not been examined, but specimens from them prove that the brown coal is of fair average quality. A specimen from the Sabine river gives the following proximate analysis:

Water	14.05
Volatile matter	37.35
Fixed carbon	41.25
Ash	5.65
Sulphur	1.70
	100.00

A brown coal of the variety pitch coal, from the Angelina river, sent in by E. G. Blount of San Augustine, is of distinctly lamellar structure, black in color, with pitchy lustre, without any traces of plant structure remaining. It is hard, firm, does not soil the hands either on edge or face, and contains particles of jet-like blackness.

The following is the proximate analysis:

Moisture	12.15
Volatile matter	37.14
Fixed carbon	41.19

Ash	6.50
Sulphur	3.02

The deposits of Angelina and Trinity counties belong to the same series as those just mentioned, and are of similar quality.

The Angelina county brown coal has the following composition:

Water	12.40
Volatile matter	36.37
Fixed carbon	37.77
Ash	13.46
Sulphur	Not determined.

In Houston county brown coal deposits occur at various points. Several of them are exposed in the river and stream channels, and others have been reported as being found at various depths in the digging of wells. The only deposits of any practical value are those found in the southeastern portion of the county, and at Hydes' and Westmoreland's bluffs, on the Trinity river, near the southwestern corner. These have a greater known development than those of any other section, but the analyses of specimens from near Calthorp in the east, and Hydes' bluff in the west, show them to have a large proportion of ash.

The southwestern field is the extension of a much greater deposit lying in Trinity county to the south. The western limit of the field enters Houston county near the southeastern corner of the W. D. Reed headright on Piney creek, and passes in a generally northern direction a little to the west of Dodsonville postoffice, to the southwest corner of the W. E. Long headright. From this point the line of outcrop turns east as far as Cochino bayou. Crossing the bayou, the eastern boundary, so far as known, extends in a southeasterly direction to and across the county line, on the John Applegate headright. The total area of this field is approximately fourteen square miles. The average thickness of the brown coal is from four to six feet, and its quality is shown in analyses given.

In the western part of the field, the brown coal, as seen in the four-foot deposit on Flat creek, is bright and glossy when first dug, but soon loses its color and becomes a dull lustreless black, with small, rounded, bright, glossy, bituminous-looking patches or spots scattered sparingly through the mass. It breaks readily into cuboidal blocks, and when dry has a tendency to crumble. On the eastern side of the field, at Rice's, the exposures when dug into show the brown coal to have a dull brown color.

In structure this field appears to be slightly trough-shaped, the brown coal deposits having an increased thickness toward the centre. A section on the Wallace headright, near the western edge, shows it to have a thickness of four feet, and to be overlaid by a thinly laminated dark colored sandy clay.

Section in Flat creek, J. Wallace headright:

1. Gray sandy surface soil..... 1 foot.
2. Coarse gray sand, with occasional deposits of coarse gravel and pebbles..... 14 feet.
3. Thinly laminated sandy clays..... 4½ feet.
4. Brown coal, visible..... 4 feet.

About two hundred yards further west, on the same headright, the brown coal forms the bottom of the creek for nearly one hundred feet, and has thinned out to about one foot. It is underlaid by a purple colored clay, and lies much nearer the surface than where it has greater thickness. This exposure shows a section of:

1. Dark gray sandy soil..... 1 foot.
2. Gray sand..... 5 feet.
3. Laminated clay and sand..... 4 feet.
4. Gray sand..... 3 feet.
5. Brown coal..... 1 foot.
6. Purple clay..... .....

The section shown in a stream near Mr. A. Rice's house, on the J. Bethed headright, shows a nearly similar structure:

1. Yellow gray sandy surface soil..... 1 foot.
2. Gray sand with ferruginous pebbles, fine gravel seen in hill..... 20 feet.
3. Thinly laminated brown colored clay and sand with interlaminæ of carbonaceous matter..... 4 feet.
4. Laminated brown or pink clay..... 1 foot.
5. Brown coal..... 4 feet.

Throughout the intermediate region underlaid by the brown coal the sections wherever shown are practically the same as those given. The coal appears in the streams in every place where the cutting is deep enough to reach it, and it is also found in the well borings. On the W. Z. Millen headright it is six feet thick, and lies at a depth of thirty feet. Three miles northeast of the southwest corner of the J. B. Trenery headright it comes up to within eighteen feet of the surface.

The southwestern brown coal field is best developed at Hydes' and Westmoreland bluffs, on the Trinity river. At Hydes' Bluff the outcrop extends from near the ferry nearly half a mile in a southeasterly direction. The section of bluff shows:

1.	Yellow sandy loam, changing into ashy gray on top where cultivated	8 feet.
2.	Conglomerate of ferruginous and siliceous pebbles, broken pieces of nodular iron ore, ferruginated and silicified wood and brown sand	2 feet.
3.	Dark blue sandy clay, having one foot of laminated brown sandy clay on top, in contact with the conglomerate, the dark blue clay containing more or less of iron pyrites	10 feet.
4.	Soft lignite, very friable and mixed with sand, in deposition very irregular, and extending from two inches to	2 feet.
5.	Light gray sandy clay, the clay becoming more prevalent towards the base of the bed	10 feet.
6.	Brown coal	2 to 6 feet.
7.	Dark purple clay	1½ feet.
8.	Gray sand, containing nodules of sandstone	4 feet.

The lower bed of brown coal at this place is very pronounced, and forms a ledge in some places six feet wide along the face of the bluff. In texture, it is strong and solid, of a dark glossy lustre when first mined, which it retains for some time, but ultimately becomes a dead black, with pitchy streaks. No woody structure visible. Compact, uneven to even fracture, shrinkage cracks parallel with and perpendicular to plane of bedding.

This bed is four feet thick, is from six to fifteen feet above low water level, and is easy of access. It breaks in large cuboidal blocks, and disintegrates slowly when exposed to the air. Its composition is very variable, changing materially at different portions of the bed. One analysis given shows it to have 16.70 per cent of ash, but another determination of a specimen not many yards distant showed only 7 per cent of ash. It is probable that the brown coal from this deposit may, with the good facilities for transportation at hand, be utilized.

ANALYSIS.

Moisture	13.10
Volatile matter	41.65
Fixed carbon	36.80
Sulphur	.90
Ash	7.55
	100.00

On the Bethed headright there is an earthy brown coal bed varying from four to six feet in thickness. Color, light chocolate brown on face; darker where freshly broken. A few blacker laminæ and spots are scattered through it, and it grades upward into an impure sandy coal with much mica. It is a true brown coal, however, in showing no distinct

woody structure; is massive, tolerably firm, gives fatty streak under the finger nail. Soils the fingers. The specimen taken from the outcropping probably contains a larger per centage of ash than would be found in the average of the deposit. Fracture uneven.

ANALYSIS.

Moisture	4.90
Volatile matter	40.73
Fixed carbon	20.93
Ash	32.90
Sulphur	.54

ANALYSES OF BROWN COAL FROM HOUSTON COUNTY.

	Volatile matter.	Fixed carbon.	Ash.	Water.	Sulphur.	Total.
No. 1	36.06	32.56	16.70	11.80	0.88	100
No. 2	32.96	22.01	40.03	4.52	0.48	100
No. 3	40.65	30.95	19.75	7.75	0.90	100

Localities.

No. 1. Hydes' Bluff.
No. 2. A. Rice's place, J. Bethel headright.
No. 3. Wallace headright, near Calthorp.

In Grimes county thin seams of brown coal occur in the neighborhood of Killian Springs, and stretch across the county in a northeasterly direction as far as the Bedias postoffice, near the northeastern corner of the county. A seven foot deposit of brown coal also occurs in Tanyard creek, on the Boatwright headright, near Piedmont Springs. This coal is of the brown grade throughout the upper three feet and is mixed with a brown clay, while the lower four feet, of blacker color, is too much mixed with a black sand to be of any economic value.

In the record of a boring at Lamb Spring, fifteen miles north of Navasota, brown coal has been reported at various depths and having various thicknesses. Roughly, the section of this well shows:

1.	Brown coal, first seam at 12 feet	2 feet thick.
2.	Brown coal, second seam at 34 feet	2½ feet.
3.	Brown coal, third seam at 38 feet	2 feet.
4.	Brown coal, fourth seam at 41 feet	7 feet.
5.	Brown coal, fifth seam at 52 feet	10 feet.

Several deposits of brown coal are reported as occurring deeper in the boring, but all are accompanied by water. A small deposit of coal also occurs in the bank of the Navasota near Sulphur Springs.

Although lignitic strata of sands and clays occur throughout the whole of the northern half of Brazos county, no brown coal of any commercial value is known to occur except at Niblitz or Black Shoals in the Brazos river, in the northwestern portion of the county. The brown coal shown at this locality stretches across the river into Burleson county. A section of the river bank shows the following:

1.	Bluff loam river deposits	6 feet.
2.	Brown clay	3 feet.
3.	Yellow sand, with gravel near bottom	10 feet.
4.	Brown coal, shaly near top. but becoming compact at bottom of bed	12 to 14 feet.
5.	Lignitic sand	.....

In the Yegua clays and sands of Fayette county we find the brown coal deposits which accompany them from the Sabine westward.

The brown coal bed near the mouth of Barton's creek is from two to four feet thick, with some lignite, and is of a decidedly black color. It is overlaid and underlaid by interbedded and interlaminated gray and chocolate clays and sands. The exposure is two hundred yards in length and shows a fault with a throw of ten feet.

The principal outcroppings of brown coal on the Colorado river in Fayette county begin about twelve miles above LaGrange at Chalk Bluff. From this point to LaGrange there is a succession of outcrops in the bluffs which border the river on one side or the other, the beds being usually from three to six feet in thickness. In the upper or first Chalk bluff we have an exposure probably half a mile long, which shows a bed of lignitic brown coal some five feet in average thickness, which passes under the water about midway the length of the bluff. Other thin seams of brown coal and specks of lignite also occur in the bluff. Similar small deposits occur between this point and second Chalk bluff. At this latter bluff we have a section one hundred and sixteen feet in vertical height, which shows four thin seams of brown coal from one to two feet in thickness. These are separated by beds of light green or chocolate clays. From here to Palm Bluff similar deposits with many brown coal beds were passed, the heaviest of which is that at Manton's Bluff.

This series of interbedded and interlaminated sands and clays with brown coal deposits is also exposed along the line of the Missouri, Kansas and Texas Railway between West Point and Upton.

The principal outcrop on the Colorado is at Manton's Bluff, on the west

side of the river, about four miles above LaGrange. The following section was made at this point:

1. Gravel and fragments of the underlying sandy materials..... 10 feet.
2. Cross-bedded light colored sands..... 5 feet.
3. Laminated clayey sands, weathering white, with ferruginous partings..... 5 to 10 feet.
4. Brown coal, variable in quality. In places common brown coal, at others earthy brown coal and apparently pyropissitic, some pitch coal and mineral charcoal, quantities of lignite..... 15 feet.
5. Black lignitic clays, with leaf impressions—exposed..... 20 feet.

Dip between 1 and 2 degrees.

O'Quinn creek shows a series of six seams of lignite interbedded with sands and clays. These brown coals vary from one foot to eight feet in thickness and are of excellent quality.

Analyses of brown coal and lignite from different portions of the Manton Bluff exposure gave the following results—all surface specimens:

	1.	2.	3.	4.
Moisture	15.30	13.90	18.15	33.80
Volatile matter	35.16	29.90	34.45	31.17
Fixed carbon	39.56	14.65	28.40	23.72
Sulphur	3.68	1.50	3.20	4.06
Ash	6.30	40.65	15.80	7.25

No. 1. Earthy brown coal. Friable and smeary: color dark brown, with occasional pitchy spots: fracture uneven.

No. 2. Earthy brown coal. Similar to No. 1, but from top of seam: of lighter brown color and somewhat more friable.

No. 3. Lignite. Distinct woody structure: black in color: occurs abundantly in No. 4.

No. 4. Brown coal: brownish black: massive, with traces of lignitic material; fracture uneven, lustre dull: fatty streak under finger nail, slightly smeary; shrinkage cracks irregular. This represents the body of the 15-foot bed as exposed in the river bank.

CHAPTER IX.

TEXAS BROWN COAL COMPARED WITH THAT OF EUROPE AND WITH BITUMINOUS COAL.

The standard of comparison of fuel values with us at the present time is that of the one in most general use—bituminous coal. In any effort, therefore, to introduce any other fuel as a substitute for such coal, in whole or in part, there must be proved its power to perform the same work with equal facility and at a cost equal or less than coal, before any headway can be made with it; and even then, its progress into popular favor may be very slow, since the conservatism of the people is usually so great that they prefer to continue the use of that with which they are entirely familiar, unless very decided advantages are to be obtained by making a change.

It can not be claimed that raw brown coal is or can be (other than under most exceptional and extraordinary conditions) the equal of the best raw bituminous coal as a fuel, weight for weight. Its higher contents of hygroscopic water would of itself prevent such an equality.

But it may be claimed, and is readily susceptible of proof, that when the entire range of conditions which make up the value of a fuel are taken into consideration, brown coal, such as that which is found in our State, is a fuel which can and will replace bituminous coal advantageously for many domestic and industrial uses.

In Europe such a substitution is no longer theoretical, but has long been practiced, and the use of brown coals is constantly on the increase. That this is true, is shown most conclusively by the following statistics of the amounts of bituminous coal and brown coal respectively which have been mined in Germany, Austria and Italy during the periods stated. These figures are taken from the official reports of the different governments, and are therefore thoroughly reliable.

TABLE NO. 6.

Production of Bituminous Coal and Brown Coal in the Austrian Empire from 1881 to 1891.

Year.	Bituminous Coal.		Brown Coal.	
	Tons.	Value.	Tons.	Value.
1881	6,340,000	$10,370,000	8,960,000	$8,010,000
1882	6,560,000	10,720,000	8,996,000	8,470,000
1883	7,190,000	11,435,000	9,854,000	9,145,000
1884	7,190,000	11,385,000	10,009,000	9,040,000
1885	7,380,000	11,335,000	10,514,000	9,130,000
1886	7,420,000	11,150,000	10,930,000	9,335,000
1887	7,790,000	11,435,000	11,570,000	9,040,000
1888	8,270,000	11,990,000	12,860,000	10,370,000
1889	8,590,000	13,325,000	13,850,000	11,430,000
1890	8,930,000	15,200,000	15,329,000	13,820,000
1891	9,192,884	16,842,350	16,192,073	15,380,000

Of this amount the greater part was produced in Bohemia, where during the past thirty years the production has increased 1500 per cent, as is shown by the following table:

TABLE NO. 7.

Production of Brown Coal in Bohemia from 1861 to 1891.

Year.	Tons.	Value.
1861	715,068	$549,956
1866	942,836	677,230
1871	2,314,926	2,289,152
1876	4,785,572	3,751,030
1881	6,538,720	4,367,488
1886	8,390,319	5,496,680
1887	8,865,673	5,656,123
1888	9,973,600	6,371,298
1889	10,880,142	7,294,240
1890	12,190,932	9,151,309
1891	12,965,304	10,422,143

The marked increase in production and value of this brown coal is of special interest to us, since the character of coal mined in this kingdom is most nearly like that of Texas.

Hungary shows also a similar increase in the production of brown coal.

TABLE NO. 8.

Production of Brown Coal and Bituminous Coal in Hungary.

Year.	Tons Brown Coal.	Tons Bituminous Coal.
1880	1,101.000	785,000
1890	2,025,000	945,000

The conditions in Austria are similar to those of Texas. Bituminous coal deposits are found there, and they are of good quality, but they are not equal in extent to the deposits of brown coal, and since the value of the brown coal has come to be generally recognized, its output has increased until it is now nearly double that of bituminous coal.

Italy imports by far the larger portion of coal which is used, but the mining of brown coal is increasing. At present the greatest proportion of the fuel used is brought from England.

TABLE NO. 9.

Production and Imports of Fuel in Italy.

Year.	Production. Brown Coal Mined. Tons.	Importation. Coal, Brown Coal and Coke. Tons.
1871	80,336	791,389
1876	116,399	1,154,223
1881	134,582	2,073,313
1882	164,737	2,180,020
1883	214,421	2,351,092
1884	223,322	2,605,051
1885	190,413	2,957,436
1886	243,325	2,927,092
1887	327,665	3,575,059
1888	366,794	3,872,905

In Germany the conditions are different. The great coal beds of Silesia, Westphalia, and the Rhine Provinces, with other smaller districts, yield a vast amount of excellent fuel, while the brown coal deposits, although they are of great extent, produce a fuel of a more friable nature than that of Austria, and of which nearly one-half the entire weight is moisture. This greatly reduces its comparative value for fuel purposes in competition with a large and reasonably cheap supply of bituminous coal. Persistent effort, however, has been so well directed that by briquetting the poorer brown coal it has been brought into general use, and the better grade finds ready market as it is mined.

The increase in the production of brown coal has thus kept step with that of bituminous coal, even under these comparatively unfavorable conditions.

TABLE NO. 10.

Production of Bituminous Coal and Brown Coal in the German Empire from 1868 to 1891.

Year.	Bituminous Coal.		Brown Coal.	
	Tons.	Value.	Tons.	Value.
1848	.....	.....	1,217,783	$718,772
1858	.....	.....	2,908,352	2,191,588
1868	22,731,532	$31.272,067	5,602,323	3,874,688
1878	35,500,167	44,511,402	8,841,366	6,997,777
1879	37,674,648	48,723,201	9.278,354	7.198.879
1880	42,172,944	52,654,266	9,874,888	7,541,442
1881	43.780,545	54.243.490	10,412,153	7,817,248
1882	47.097,376	58,181,125	10,798.091	7,392.681
1883	50.611,018	63.830,714	11,826,630	7,938,888
1884	51.867,646	65.142,853	12,055,697	7,983,083
1885	52.879.004	65.720,500	12,387,284	8.092.631
1886	52.482,799	64,438,905	12,565,405	8.002,941
1887	54,548,283	65,977,149	12,696,487	7,968,051
1888	59,475,351	72,979,734	13,207,888	8,039,837
1889	61,436,991	83,145,265	14,205,047	8,832,033
1890	64,373,816	119,880,961	15,468.434	9,967,812
1891	67,528,311	.....	16,818,845	.....

In addition to the continued increase of production by the German brown coal mines, the imports of Bohemian brown coal have also increased, and in even greater ratio, as is shown below:

TABLE NO. 11.

Amounts of Bohemian Brown Coal Imported into Germany.

Year.	Tons.
1872	1,016,733
1873	1,489,071
1874	1,977,635
1875	2,415,704
1876	2,431,523
1877	2,455,090
1878	2,588,970
1879	2,850,021
1880	3,066,545
1881	3,051,958
1882	3,010,049
1883	3,306,610
1884	3,451,787
1885	3,634,987
1886	4,068,023
1887	4,408,043
1888	5,189,698
1890	6,506,404
1891	6,805,581

From these tables it is apparent that even with a plentiful supply of bituminous coal at relatively low cost, brown coal has come into general use as fuel, not only in the immediate vicinity of the localities at which it is mined, *but is freighted equal distances with the bituminous coal* (in the case of the imports of Bohemian brown coal), *and meets it in open competition on a basis of actual value as fuel.*

The steady increase in the use of brown coal for general purposes is best shown by the following table of the receipts at Berlin for the past twelve years:

TABLE No. 12.

Receipts of Fuel at Berlin.

Year.	Bituminous Coal. Tons.	Brown Coal. Tons.	Total. Tons.
1880	1,051,179	307,808	1,358.987
1881	1.018,854	375,779	1.394.633
1882	1,023.525	362,861	1.386.386
1883	1,022.208	408,828	1,431.336
1884	1,065.340	445.615	1.510.955
1885	1,139,391	514.612	1.654.003
1886	1.190,570	534,205	1,724.775
1887	1.203.251	550,972	1.754.223
1888	1,291.510	653,721	1,945,231
1889	1.319.957	678,902	1.998.859
1890	1.406.961	707,683	2,114.044
1891	1,332,384	778,528	2,110.912

From these statistics, which are compiled from official returns, it will be seen that while the increase in the use of bituminous coal in Berlin is only a little over 25 per cent, that of brown coal is over 150 per cent, and that the increase in actual tonnage is 470,000 tons of brown coal against 280,000 tons of bituminous coal. Or, to make the comparison on a still different basis, the proportion of brown coal used in Berlin has increased from 22 per cent of the total supply in 1880 to 37 per cent in 1891.

In addition to its steady increase in consumption as fuel the brown coals of Germany have become the basis of a great industry in the manufacture of paraffine and mineral oil.

The German Brown Coal Association reports for the years 1889, 1890 and 1891, the following statistics of production and use of brown coal by members of the Association:

	1889.	1890.	1891.
Number brown coal mines	.....	149	136
Number factories of nass-press-stein	.....	47	44
Number factories of briquettes	.....	47	47
Number tar distilleries	.....	51	49
Number mineral oil factories	.....	13	14
MINES.			
Number operated	145	143	125
Production in tons	9,930,588	10,104,505	9,420,145
Value at mines	$6,081,092	$6,502,443	$5,611,100
FACTORIES OF NASS-PRESS-STEIN.			
Number factories	43	45	35
Number presses	57	61	46
Number tons brown coal used	561,853	606,039	521,633
Thousand bricks made	325,317	343,857	292,172
Value per thousand	$1.96	$1.99	$1.92
BRIQUETTE FACTORIES.			
Number operated	48	46	40
Number presses	130	130	119
Tons brown coal used	2,371,754	2,467,423	2,490,609
Tons briquettes produced	858,250	935,130	944,437
Value of briquettes	$1,834,990	$2,036,563	$2,052,508
TAR DISTILLERIES.			
Number in operation	.....	51	46
Retorts, upright	1,106	1,206	1,226
Retorts, horizontal	114	40	40
Tons brown coal used	1,271,535	1,256,689	1,483,161
Tons tar produced	49,475	52,798	57,200
Tons coke produced	232,900	241,300	263,334
Value tar	$932,614	$1,306,245	$1,108,615
Value coke	$303,873	$376,528	$406,245
MINERAL OIL FACTORIES			
Number in operation	.....	.....	12
Tar used.....tons	55,553	52,220	55,149
Production hard paraffine.....tons	4,787	5,298	4,817
Production soft paraffine.....tons	2,233	2,958	2,141
Paraffine candles.....tons	5,590	5,358	6,083
Solar oil.....tons	5,467	5,404	4,905
Paraffine oil, yellow.....tons	7,095	6,562	6,150
Paraffine oil, dark.....tons	15,454	19,545	18,158
Value of products	.....	$2,614,768	$2,732,864

From the facts and figures given here and in the previous pages of this Report, it must be apparent to everyone that the possibility of substituting brown coal for bituminous coal is not only recognized in all parts of Europe, but is being acted on wherever a sufficient quantity of suitable brown coal exists for exploitation and the demand exists for fuel in any quantity.

If then the substitution of brown coal for bituminous coal be possible in these countries to the extent shown by these official reports, we may well compare the brown coal of Texas with those which are thus substituted, to ascertain their relative values. For this purpose I have had specimens of many of the deposits of brown coal in Texas submitted to elementary analysis by the chemists of the Survey, Messrs. Magnenat and Wooten, and the results are given herewith, followed by similar analyses of the European brown coals taken from every district which in any way nearly resembles ours.

It must be borne in mind, however, that the analyses of European brown coals are made of materials taken from mines fully opened, and which are therefore entirely free from the results of long continued action of atmospheric influences, while many of those of our Texas brown coals which I submit for comparison are simply from the outcrop of the coal bed. Indeed, only four of the specimens analyzed can be said to be anything like fair representatives of the contents of the beds. The balance are almost necessasily poorer than the body of the coal will be when opened up. The four are those last taken from Robertson, Milam, and Medina counties, numbers 18, 19, 21, 22.

The comparisons made here are based upon the relative amount of combustible matter (carbon and hydrogen) contained in the various fuels, and while this is as usual calculated on the basis of the coal after the moisture has been driven off, I have given wherever possible the amount of moisture which occurs in the freshly mined coal, so that a comparison of values, ton for ton, may be made if desired.

ANALYSES OF TEXAS BROWN COALS.

Composition of coals dried at 105 degrees C. to a constant weight.

Locality.	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Sulphur.	Ash.	Water in Freshly Mined Coal.
1. Bowie county.....	59.84	3.10	26.97	1.00	9.10	10.67
2. Wood county.....	56.33	4.29	24.13	.84	14.39	10.85
3. Gregg county.....	60.79	4.96	23.68	.88	9.27	12.00
4. Harrison county.....	66.32	3.95	21.56	2.20	8.97	13.35
5. Morris county.....	59.87	4.70	24.35	2.42	8.66	8.55
6. Rains county.....	57.04	4.01	24.48	1.11	13.35	.....
7. Rains county.....	59.32	2.80	20.27	.98	16.63	.....
8. Smith county.....	57.40	3.60	23.31	.95	14.74	9.83
9. Anderson county	53.06	4.06	24.12	1.02	17.74	.....
10. Rusk county.....	58.93	4.20	22.14	4.64	10.09	16.63
11. Cherokee county.....	66.67	3.81	22.08	1.64	5.83	.....
12. San Augustine county.	61.12	3.32	24.53	3.39	7.75	.....
13. Leon county.....	63.60	4.08	24.02	.55	7.79	.....
14. Houston county.....	63.09	3.64	22.56	1.03	9.68	.....
15. Lee county.....	62.48	3.21	20.80	1.95	11.56	16.50
16. Webb county (outcrop)	59.28	5.29	16.98	.89	17.56	.....
17. Milam county.....	60.93	4.12	22.27	1.32	11.36	.....
18. Milam county.....	62.50	5.45	20.84	.97	7.54	17.75
19. Milam county.....	64.50	5.37	20.76	.81	8.56	18.25
20. Robertson county.....	58.16	4.46	13.11	1.50	12.77	.....
21. Robertson county.....	65.14	5.29	19.28	1.15	9.21	16.40
22. Medina county.....	60.92	2.57	25.34	1.47	9.70	13.25

ANALYSES OF GERMAN BROWN COALS.

	Specific Gravity.	Water-free. Carbon.	Hydrogen.	Oxygen and Nitrogen.	Sulphur.	Ash.	Water.	Character.	Analysis by	Authority.
1. Riestedt, Saxony....	1.218	61.13	5.09	31.95	.....	1.83	31.66	Lignite.....	F. Bischof.....	Zincken.
2. Loederberg.....	1.219	55.30	4.90	31.95	.....	7.85	49.50	Earthy brown coal....	F. Bischof.....	Zincken.
3. Teuditz.....	1.263	54.02	5.28	27.90	.....	12.80	48.60	Earthy brown coal....	F. Bischof.....	Zincken.
4. Teuditz	.....	49.91	5.20	32.42	.....	12.47	.....	Earthy brown coal....	Wagner.....	Zincken.
5. Brumby	1.263	47.78	4.28	18.42	.....	29.52	40.60	?	.....	Percy.
6. Frankfort a. d. Oder.	.....	59.65	4.86	26.41	.....	9.08	16.07	Earthy brown coal....	Heintz.....	Percy.
7. Halle a. d. S.....	.....	60.94	5.17	21.63	.....	12.26	45.00	Common brown coal ...	.....	Schultz.
8. Halle a. d. S.....	.....	59.00	5.50	24.00	.....	11.50	45.00	Common brown coal ..	F. Bischof.....	Preissig.
9. Nachterstedt.....	.....	59.52	5.37	24.15	.....	10.96	.....	Common brown coal ..	Dr. Zerener.....	Preissig.
10. Meuselwitz	.....	63.51	4.87	23.64	.....	7.98	.....	.....	?	Preissig.
11. Average of 17 different mines.	.....	55.36	5.09	25.20	.....	14.35	.....	Common brown coal ..	F. Bischof, Heinz, Wagner, etc.	Preissig.
12. Bitterfeld	.....	54.14	4.22	24.72	.....	16.00	.....	Common brown coal ..	?	Preissig.

Analyses of Austrian Brown Coals.

	Specific Gravity.	Water-free. Carbon.	Hydrogen.	Oxygen and Nitrogen.	Sulphur.	Ash.	Water.	Character of Coal.	Analyst.	Authority.
1. Wildshut, Up. Aust..	1.306	53.79	4.26	25.39	0.98	15.58	26.15	Lignitic brown coal...	Schroetter.....	Zincken.
2. Thallern, Austria...	1.413	49.58	3.84	22.68	4.56	19.34	22.53	Blackish-brown lignite	Schroetter.....	Zincken.
3. Gloggnitz, Austria..	1.364	57.71	4.49	22.14	3.12	12.54	25.15	Lignitic fissile brown coal.	Schroetter.....	Zincken.
4. Schoenfield, Bohm..	.....	61.20	5.17	21.28	.....	12.35	21.20	Common brown coal ..	Heintz....	Zincken.
5. Schoenfield, Bohm..	.....	64.68	5.30	21.37	.....	8.65	.....	.....	.....	.....
6. Teplitz	.....	57.36	4.28	17.64	0.45	3.00	17.25	.....	.....	.....
7. Teplitz, Komotau...	.....	58.29	4.68	18.42	0.71	5.30	12.60	.....	.....	.....
8. Teplitz, Eger	.....	49.67	4.15	13.00	1.03	12.90	19.25	.....	.....	.....
9. Reichenau, gas coal.	.....	68.07	6.84	14.43	.....	10.66	.....	Gas coal	Dr. Bauer.....	Preissig.
10. Neusattler	.....	70.24	5.83	18.60	.....	5.33	.....	Gas coal	Dr. Wittstein....	Preissig.
11. Dux	.....	67.88	5.55	19.85	.....	6.72	.....	Grate coal	Dr. Bemte.....	Preissig.
12. Dux, Victoria mine.	.....	69.66	5.15	19.59	.....	5.60	.....	Grate coal	Dr. Nevole	Preissig.
13. Koenigsberg a. E. Low	.....	69.29	6.97	18.12	.....	5.62	.....	Light brown coal	Dr. Bemte.....	Preissig.
14. Koenigsberg, Upper.	.....	61.41	5.73	20.23	.....	12.63	.....	Dark brown coal.....	Dr. Bemte.....	Preissig.
15. Leoben	.....	57.92	5.22	23.86	.....	11.00	.....	Glance coal	.....	Zincken.
16. Hrastewitz	.....	77.08	4.46	13.86	.....	1.60	.....	Pitch coal.....	.....	Zincken.

ANALYSES OF ITALIAN BROWN COALS.

Free of Water and Sulphur.

	Specific Gravity.	Carbon	Hydrogen.	Oxygen and Nitrogen.	Ash.	Sulphur.	Water.	Authority.
Monte Bamboli .	1.32	73.44	6.15	15.31	5.10	2.34	.....	Capacci
Casteani.....	1.30	60.10	5.23	26.62	8.05	1.02	17.00	Capacci
Gonnessa	.....	59.98	4.75	29.42	5.85	0.94	6.72*	Capacci
Borgotaro	1.33	77.00	5.70	11.10	5.90	.....	6.50*	Capacci
Murlo	.....	57.58	4.92	28.00	5.30	1.70	30.00	Capacci
Monterufoli	1.35	57.16	5.01	26.68	11.15	3.86	14.50*	Capacci
Bolca	1.53	47.18	4.00	31.02	17.80	.....	.....	Capacci
San Giovanni...	1.20	55.36	5.66	32.98	6.00	0.462	40.00	Capacci

* Air-dried.

These tables show that the brown coals of Texas are very similar in composition to the Bohemian, as has been stated previously, and that while the ash is slightly heavier in the Texas coals than in the best Bohemian, the water content is proportionately lower. The calculated calorific power shows their relative heating capacity.

The Italian brown coals are of similar composition and value, and all are superior to the brown coals of Germany, even in the composition of the thoroughly dried material. If to this we add the fact that the German coal contains from two to three times the amount of moisture when freshly mined that is found in the Texas coals, the difference becomes still more marked.

The great value of our coals may be further seen by a comparison of the analyses of those taken from the mines which have been opened, with the briquettes made from German and Austrian brown coal without bond, as given by Preissig:

BRIQUETTES.

	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ash.	Water.	Sulphur.
Bruehl (near Cologne).....	53.50	3.90	20.09	4.66	17.85	0.52
Roddergrube (near Cologne).	52.14	3.61	20.99	6.69	16.57	0.85
Bitterfeld	49.26	3.72	21.04	11.86	14.12	.....
Koenigsberg a. E....	56.92	5.54	15.42	5.92	16.20	0.76
Koenigsberg a. E.....	50.82	4.36	17.18	8.85	18.79	1.53

TEXAS BROWN COALS, FRESHLY MINED.

	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ash.	Water.	Sulphur.
Robertson county.....	54.46	4.41	16.07	7.70	16.40	.96
Milam county, upper.....	53.64	4.48	17.13	6.20	17.75	.80
Milam county, lower.....	52.73	4.79	16.97	7.00	18.25	.66
Medina county.....	52.85	2.25	21.99	8.40	13.25	1.26

This shows most plainly that those specimens of Texas brown coals which can be said to represent with approximate fairness the deposits of that material, are in themselves, as they come from the mines, of equal value with the German brown coals, even after the latter have been manufactured into briquettes.

It is, therefore, I think, unnecessary to offer further proof of the excellence of our coal as compared with that which has come into general use in direct competition with bituminous coal of good quality, or of the possibility of making similar use of it.

It may be well, however, to show its relative value as fuel compared with the various bituminous coals which are now being used in the State.

Through the kindness of the different railroads I have been supplied with what were considered fair average specimens of the coals used on the different lines, and submit the following analyses made in the laboratory of the Survey:

ANALYSES OF COAL USED ON THE RAILROADS OF TEXAS.

Mines.	Carbon.	Hydrogen.	Oxygen and Nitrogen	Sulphur	Ash.	Heat Units in water free. C.
3. Ratone Coal & Coke Co:.	71.62	4.88	14.04	1.52	7.92	6909
5. Hondo mines.....	71.39	4.08	5.17	1.67	17.39	6996
8. Cohaba	73.78	5.91	14.75	1.48	4.08	7401
2. Ratone Coal and Coke Co.	80.07	3.21	10.37	1.46	4.89	7175
1. Kansas and Texas.....	74.70	3.25	16.04	1.44	4.57	6813
7. Texas and Pacific.....	70.72	4.76	13.42	2.20	8.90	6836
6. Osage	78.50	4.02	12.49	.76	4.23	7218
4. Hartz.....	74.17	3.01	10.06	1.58	11.15	6651

If we compare these values with the water free material of the four Texas brown coals which best represent the deposits, we have

	Heat Units.
Robertson county	6289 C.
Milam county, upper seam	6266 C.
Milam county, lower seam	6205 C.
Medina county	4766 C.

against 5813 to 7401 C. heat units in bituminous coal brought in from outside the State. This gives the relation of dried Robertson county brown coal to dried Osage coal 6289 to 7218 and means that properly burned the heating power of the dried brown coal is 87 per cent of the Osage coal. If, however, we take the same coals in their natural state, we find that while the Osage coal contains only from 2 to 4 per cent of moisture the Robertson county brown coal carries 16.40 per cent. Calculating the calorfic values on this basis, that is to say on the actual conditions of the brown coal as it comes from the mines, we have the calorfic value of 5030 C., or somewhat over 69 per cent of the value of the Osage coal. Therefore if each fuel were burned under the conditions suited to its character, their relative fuel values and consequently the relative money value would be as 7 to 10.

The data for comparison of fuel values of the other coals and brown coals are supplied by the analyses and heat units calculated therefrom, as given in the tables. Of course in actual use these values will be found only approximate, and the nearness with which the calculated values are secured will depend upon the manner of burning and the exactness with which the requirements of the fuels are met by arrangement of grates, draught, and the means of utilizing all the heat arising from the combustion. But in the absence of any means of making comparative tests in the production of steam on a practical scale and suitable grate conditions, the values derived from calculation afford the best basis for comparison which are accessible, and from the comparisons made on this basis there can be no question as to the certainty of it being possible to substitute our Texas brown coal for the bituminous coal now in use, and which is imported into the State in such great and constantly increasing quantities. All that is needed is that it shall be taken hold of and managed in a fair business like manner, with a clear understanding of its advantages as well as its disadvantages as compared with bituminous coal, and a market can be made for it at as remunerative prices as any which are now received from mining bituminous coal, and equal if not better satisfaction given.

CHAPTER X.

UTILIZATION OF TEXAS BROWN COALS.

From the foregoing facts I think it is made clear that there is in Texas brown coals a supply of material which will serve as fuel, and which will be both effective and cheap.

The question then naturally arises as to the best methods of its utilization.

This was the end to be attained by the investigation, and for that reason I have used so much of the report to show what is being done with similar coal in Europe, and in reproducing, as has been done, illustrations of the machinery, apparatus and contrivances by which similar fuels are successfully used.

The principal methods of utilizing brown coal in Europe are as fuel and in the manufacture of paraffine and illuminating oils. While many other uses are made of it, they are of minor importance, and are at present practically inapplicable to Texas.

The manufacture of paraffine and illuminating oils, which is an industry of great extent in Germany, is carried on, as has been already stated, with a special variety of brown coal which is called tar coal. In this country the distillers of petroleum manufacture sufficient paraffine for all demands, and unless there were some special demand for greater quantities there would be little inducement to look to our brown coal as a source of supply. Nevertheless, as it is one of the methods of use, I have had numerous tests made in the laboratory, and in Germany, to ascertain the possibility of the use of our brown coal in this manner.

The German tar coal and brown coal which is used for this purpose carries from 45 to 55 per cent of water, and a higher percentage of hydrogen than is present in any of the Texas brown coals yet analyzed.

The experiments made by Dr. Krey, of the Riebecksche Montan-Gesellschaft, at the Webau factory of that company, on specimens of air-dried Texas brown coal which I furnished him, seem to prove that while the percentage of tar is sufficiently high, its composition is not such that it

will yield a sufficient amount of oils and paraffine to render its distillation profitable.

Dr. Kiey reports that the air-dried coal gave on distillation at the temperature for producing the maximum amount of tar:

Tar	5.56
Coke	45.40
Water	39.96
Gas, loss	9.08

The water had an alkaline reaction, but contained only 0.544 grams of ammonia to 1000 liters of water — too small an amount for recovery as sulphate or hydrate.

The tar produced was subjected to the usual tar analysis and yielded:

Raw oil, paraffine free	7
Raw oil, containing paraffine	70
Water	1
Coke	2
Loss as gaseous matter	20
	100

This loss of 22 per cent as coke and gas is much greater than that of the tar coal, which is at most only five per cent.

The yield of hard paraffine (melting at 52 C.) was eight per cent of the tar, which, as will be seen from the statistics on page 211, is equal to the yield from the German tar. The paraffine being the only valuable product, however, the brown coal tested could not be considered a tar coal, and would not yield sufficient returns for lucrative manufacture. The coal with which this test was made was from the Angelina river, in San Augustine county. Its analysis is given on pages 198 and 213. It is possible, however, that certain deposits, especially among the upper beds of this division, may afford a variety of brown coal suitable for such manufacture should need arise for it.

The following table gives the percentage of tar which was found in the various Texas brown coals under examination:

TABLE NO. 13.

Tar Distilled from Texas Brown Coals.

Robertson county	5 to 6.5 per cent.
Milam county	7 to 8 per cent.
Lee county	8 per cent.
Medina county	6 per cent.
Smith county	8 per cent.
Bowie county	9 per cent.

Rusk county	8 per cent.
San Augustine county	8.5 per cent.
Leon county	6 per cent.
Wood county	7 to 8 per cent.

The properties of these tars will be examined, and also a careful investigation made into the composition of the upper brown coals, in hopes of finding those suitable for this use.

This brings us to the final and principal use of our brown coal — that of fuel. Fuel for household, manufacturing, railroad, iron smelting and general purposes.

The first way in which our brown coal can be used is in its raw state. While it is entirely possible to use it for household purposes in this condition in stoves or grates suitably arranged, it is altogether probable that the bulk of brown coal which will be used in this way will be in the form of briquettes, which from their form, cleanliness and convenience, will be a favorite fuel with the people whenever they are properly made and put on the market.

For manufacturing, however, where an extremely low priced and effective fuel is required, the raw brown coal must come into general use. Its abundance and distribution are such that it can be delivered in all manufacturing centers of the coastal slope at such prices as can not be duplicated, value of work considered, with stone coal, wood, or any other fuel accessible to us.

In the preceding pages have been given illustrations and descriptions of the various grates in use in Europe for burning such brown coals as ours, and by the use of these, or similar grates, the requirements for the proper combustion of the brown coal can be obtained and material be made to render approximately its full fuel value. The grates which have been illustrated and described, are such as have been thoroughly tested, and may be relied on. There may be grates of American manufacture which may prove suitable for obtaining these results, but since these latter grates have never been tested with our brown coals, and no opportunity has been afforded me for making such a test, I must perforce fall back on those which have been tried and stood the test. These are therefore presented, not only with full confidence in the performance of the grates themselves, but with a firm belief in the ingenuity of our engineers, who, having them in operation, will soon have many mechan-

ical devices for improving them, or will ascertain if any among American grates will better answer the purpose, and, if so, replace them.

Whether the raw brown coal will come into use on the various railroads, is a question which must be settled by themselves as a matter of expediency and economy. That its use is both possible and economical. is demonstrated beyond any question, and the construction of the fire boxes with which the best results have been obtained is given. On many roads, however, its use in this manner would necessitate the building of special locomotives for burning it, and these would not be useful on parts of the road where bituminous coal was in use. Its use will, therefore, probably be confined to roads which lie largely within the borders of the brown coal area, or on the southern division of those which cross it. For other roads it will probably be found most satisfactory after it has been briquetted.

In metallurgy, its use when raw can be greatly increased in combining it with coke in the smelting of iron ores and production of pig iron. As we have seen, such a combination containing from 30 to more than 50 per cent of brown coal is entirely feasible. This, when our supply of coke, even when produced from the coal of our own coal measures, has to be hauled long distances to reach the furnaces, will be of great benefit in the lowering of the cost of production.

For ginning, milling, etc., the brown coals of Texas are readily applicable by use of the grates just shown; while for burning brick, cement, lime, manufacture of stoneware, drain tile, earthenware, terra cotta and all similar materials, the raw brown coal is one of the best of fuels.

ARTIFICIAL FUEL.

The next method of utilizing the brown coal for this purpose is by manufacturing it into artificial fuel. The two methods of briquetting have been described and their differences noted. Texas brown coals have been tested by both methods.

Briquetting Without Bond.—The coals used in Germany for this purpose are the very friable earthy brown coals, containing when mined 40 to 55 per cent of water. The water is evaporated until from 15 to 20 per cent only is left, which amount has been found essential to the formation of firm briquettes, and the partly dried coal is then subjected to extremely heavy pressure. Our Texas coals are more compact

than these, and contain when freshly mined only about the quantity of moisture required for briquetting. After exposure for a season they lose a great part of this water, the air-dried coals rarely containing over 9 or 10 per cent.

In order that test might be properly made of these coals, I delivered two lots of Texas brown coals to the Zeitzer Eissengiesserie and Machinenbau-Actien-Gesellschaft at Zeitz, and Director Wendlandt had them carefully tested for their briquetting qualities on presses of their manufacture. It was not found possible, however, with the heaviest pressure that could be obtained, something over eighteen hundred atmospheres, to produce a firm and hard briquette, such as is made from the German brown coal. Whether better success may be obtained from other brown coals is of course a question, but I believe that there are among the later and more friable varieties of the brown coal of the Fayette division some deposits which could be advantageously utilized by this method. The trouble in carrying on these experiments is, however, so great as to preclude their continuance as present. In the first place, no mines are open upon the beds which might be used in this way, and sample lots taken from the outcrops would not be a fair test of the material; again, the great distance to which it must be shipped and length of time required in transmission permits the coal to dry out and alter somewhat, and thus prevents the test being made on the coal as it really occurs in the bed.

Briquetting with Bond.—The tests made with our brown coals for producing briquettes with bond were eminently successful. There have been several of these, and while all did not give equally good returns, yet the fact was fully brought out that Texas brown coals can be briquetted with a bond, and that the fuel thus produced is of most excellent character.

The only briquette factory which I inspected in Austria, which was using brown coal similar to ours, with pitch for bond, was in the vicinity of Leoben. It was owned and operated by Baron Trasche, and was used merely to briquette the slack brown coal for which there was no ready market. The factory was of the Couffinhal type which I have illustrated, and the product was a very fine fuel. The operation of this factory was in itself sufficient proof of the practicability of the production of briquettes from our brown coal by this method; but to be more certain, I shipped to the manufacturers, Messrs. Biétrix & Co., two lots of Texas

brown coal and had them test it at the factory. From their report, and specimens which are in the Museum of the briquettes from the coal sent them by me, the adaptability of the Couffinhal press for this purpose is fully proved.

In these experiments the same facts were observed as in the former experiment which was made for me at Havre; that is, that a much greater pressure is required to agglomerate our brown coal than is sufficient for forming hard and durable briquettes from the slack of stone coal. This fact will fully explain the failure of certain machines to produce serviceable fuel from brown coal with pitch as a bond. Therefore, in any attempt looking toward the utilization of our brown coals by this method care must be taken to secure such machinery as will give the necessary pressure.

The manufacturers of the Couffinhal presses, Messrs. Victor Biétrix & Co., St. Etienne, near Paris, France, state that the tests made by them serve to show that their machinery is fully and perfectly adapted to the manufacture of briquettes from our brown coal. The amount of pitch required for agglomeration will vary with the coal and the amount of pressure applied—the largest amount used by them in their experiments being between 6 and 7 per cent. A thorough drying of the brown coal was also found to be indispensable to the production of solid briquettes with a minimum of pitch. For this reason those brown coals which possess a large amount of moisture would have to be partly desiccated by means of drying ovens, and the drying completed by the furnace connected with the briquette machine, before they would be ready for agglomeration to the best advantage.

The Couffinhal presses and machinery are also manufactured in Germany by Messrs. Schüchtermann & Kremer, of Dortmund.

The prices of the machinery furnished by the factories are as follows:

PRICES OF BRIQUETTE MACHINERY.

	No. 1 Briquette Machine, making 100 tons per day of 5-lb. Briquettes.		No. 2 Machine, Making 200 tons of 10-lb. Briquettes.		No. 3 Machine, making 300 tons 20-lb. Briquettes.	
	Pounds.	Price.	Pounds.	Price.	Pounds.	Price.
Press	16,000	$5,100	36,000	$7,500	60,000	$10,000
Drying machine	20,000	1,650	38,000	2,500	40,000	2,500
Chimney for same	2,700	150	3,000	150	3,000	150
Mixer	7,000	750	15,000	1,500	20,000	2,000
Distributors	11,000	1,200	14,000	1,500	16,000	1,750
Elevator cups, etc	1,100	150	1,320	200	1,800	250
Pulverizer	2,900	750	6,000	1,000	11,000	1,250
Connections and driving parts.	9,000	800	15,000	1,250	18,000	1,550
Engine	7,000	1,250	17,000	2,000	27,000	2,750
Boiler	18,000	850	32,000	1,500	50,000	2,500
Pump and pipes, etc	1,200	350	3,600	500	5,000	600
		$13,000		$19,600		$25,300

Another press which promises well for use with Texas brown coal, on account of the strength with which it is built and the heavy pressure which can be obtained with it, is that manufactured by Messrs. Yeadon & Co., Albion Place, Leeds, England. It is in use in England, Scotland, Wales, Belgium, France, Austria, and Spain, and there are two of the presses in America—one at Cow Bay, Nova Scotia, the other at San Francisco. The ordinary pressure obtained is two tons per square inch. Three sizes of presses are made, capable of producing, respectively, fifty, seventy-five, and one hundred tons of briquettes in ten hours.

The briquette plants contain the following items:

1. Chain elevator for small coal.
2. Pitch crackers and small elevators.
3. Coal and pitch measurer.
4. Disintegrator for grinding coal and pitch.
5. Chain elevators for ground coal and pitch.
6. Superheater and furnace pipes.
7. Vertical heater and frame.
8. Briquette machine.
9. Endless carrier for finished briquettes.

10. Shafting and pulleys inside machine house.

Prices free on board at Liverpool are quoted as follows:

Plant as above to make fifty tons in ten hours, $6,250.

Plant as above to make one hundred tons in ten hours, $10,750.

For the fifty ton plant an engine 13x24 inches and boiler 20x5 feet 6 inches would be required, and for the one hundred ton plant an engine 16x30 inches and boiler 26x6 feet.

Several other presses were described in the general description of briquetting, and the prices given. Some of these may also be found suited for agglomerating our brown coal.

The only American press of which I could get any detailed information was that of the Loisseau pattern, which was designed to produce an egg-shaped fuel with an admixture of coal tar or pitch. As far as I have been able to learn the pressure obtained is not sufficient to produce the best results with our brown coal, but the experiments were not carried far enough to decide whether this could not be bettered by thoroughly drying the brown coal or by using a different proportion of pitch. As there are several presses of this pattern in use in the United States there is no reason why more extensive experiments could not be made, as the fuel, which is comparatively smokeless in combustion, would be very serviceable for many purposes.

The Bond.—One of the chief factors in the successful manufacture of briquettes by this method is a supply of pitch for bond at a low price. The pitch which is used in Europe is manufactured from the tar condensed at the coking ovens, and is reckoned at $10 to $12 per ton at the various factories where it is used. At present there is no such production of pitch in this country, the manufacturers of coke for the most part using the bee hive or similar oven and allowing the gases evolved in coking to escape into the air. A large amount of pitch is produced, however, from the tar collected at the different gas works and finds a market for paving and other purposes. How nearly this supply would come to meeting the demands for briquetting such an amount of brown coal as would be used here, were the industry once established, can not now be stated, but it must be remembered that an output of one thousand tons of briquettes per day implies the use of at least fifty tons of hard pitch for their production.

Another source of supply for such a bond is the Trinidad asphaltum,

which could be secured in sufficient quantity for the purpose, the principal question being the cost delivered at the factory.

We find, however, in our own State, a supply of suitable material which may be readily and profitably utilized in this way. I refer to the asphaltum deposits of Uvalde, Burnet, Montague, Anderson and other counties. The material occurs here in such abundance that it could be prepared for use and delivered at the works at a price far below that at which either of the other mentioned materials are quoted, and still yield a good profit to the operators.

There is therefore no reason why the manufacture of excellent briquettes from our brown coals should not be attended with abundant success, and the certainty of securing a ready market for such a fuel is not to be doubted in the least when we consider the advantages which it possesses in point of cleanliness, freedom from smoke, heating power, etc.

In this form it can be used exactly as stone coal is used for all household, industrial and railroad purpose, and although I know of no series of experiments having been tried with it, there is certainly the possibility of its use when briquetted for the smelting of iron ores, just as raw stone coal is used for this purpose in both Europe and America.

ILLUMINATING GAS.

The composition of the Texas brown coals is such that many of them can be used for the production of illuminating gas. No detailed experiments have been made with these coals on a practical scale, but the tests in the laboratory show that the volume of gas is good and its illuminating power fair. A series of laboratory experiments in regard to amount and quality of gas which can be produced from our brown coals is now in progress, and the results will be given when completed.

PRODUCER GAS.

One of the most promising uses of our brown coal is in the form of producer gas. The extremely favorable and satisfactory results obtained by the use of similar coals in Austria by this method, is sufficient to warrant the strongest statements regarding the adaptability of our brown coals for any and all purposes for which such a fuel can be utilized. This, in itself, furnishes sufficient grounds for the opening and the working of the brown coal deposits; for in this method of use, every kind of coal, from the lump to the finest slack, is serviceable, and the gas produced is,

as has already been stated, applicable for all rolling mill, metallurgical, manufacturing, and other purposes for which a gaseous fuel can be used.

SMELTING.

The utilization of our brown coals in the smelting of our iron ores has been alluded to in connection with its use in the raw state and also after briquetting. The first method of use finds its proof of practicability in the furnaces of Zeltweg, which have already been described, and the quality of some of our brown coals is such that they can be used for this purpose in connection with coke. The lines of the Zeltweg furnace have already been given, and are those which seem best adapted for this purpose.

The use of the briquetted brown coal in iron smelting has, so far as I have investigated, not yet been attempted (although briquetted stone coal is in use for this purpose in Europe), but the considerable use of stone coal for this purpose, and the relative value and character of the two fuels. render this use at least theoretically possible; and if briquettes can be obtained at sufficiently low prices, after the establishment of the factories, a trial of them in this way will be of great importance to the iron industry of the State.

COKING.

In the introduction to this Report I have spoken of my early and successful attempts at coking brown coals; under the uses of brown coal I have given the details of the recorded experiments along the same line, the results of some of which agree closely with my own. These seem to prove that brown coals can be made to coke under certain conditions. Whether such coke can be made as will be serviceable for blast furnace use, and at a price low enough to allow its employment in the smelting of iron ores, is at present not determined and somewhat doubtful. From all the experiments made it would seem necessary that the brown coal should first be charred, or at least thoroughly dried, before it is coked, with the bond of bituminous coal or bituminous coal and coal tar. If we examine the analyses of some of our brown coals we find that the coke, consisting of the fixed carbon and ash of the analyses, amounts to the following proportions in the specimens named:

	Fixed Carbon.	Ash.	Total.
Robertson county	33.42	7.70	41.12
Milam county, upper	37.40	6.20	43.60
Milam county, lower	37.28	7.00	44.28

If it be possible to form a good coke with an admixture of 10 per cent caking coal producing 66 per cent of coke (61.77 fixed carbon and 4.23 ash) we will need for the production of one ton of coke (of 2000 pounds):

	Raw Lignite. Lbs.	Coal. Lbs.
Robertson county	4,200	420
Milam county	3,950	400

And the resulting coke would contain respectively 17 and 15 per cent of ash. This percentage is somewhat large, yet is no higher than is found in some of the coke from bituminous coal. The ash of the McAlester coke amounts to 10.32 per cent, that of Connellsville coke to 11 per cent, but in some of the Alabama, Kentucky and West Virginia cokes the ash is not more than half these amounts.

In the coking of brown coal by this method, I am inclined to favor the use, in place of the bee hive or similar ovens, of such as are used in England, France and Belgium, which, while they give a larger proportionate yield of coke than is gotten by the bee hive ovens, also save the tar and ammonia by condensing the gases which are driven off. The revenue from the recovery of these substances would materially reduce the cost of making the coke in this way and amply repay the increased first cost of erection.

Whether the coke thus produced would be strong enough to support the burden of the blast furnace, can only be ascertained by actual trial. If laboratory experiments can be depended upon, many, if not all of them, would be too tender for this use. The cost would depend largely upon the price at which a supply of caking coal, in form of slack or small coal, could be laid down at the place of manufacture.

At present there is little outside a theoretical basis to work on in this direction, since it has been altogether impossible to make any experiments on a working scale, owing to the entire absence of coking ovens of any sort in the State.

There is no doubt, however, that coke produced in this way would be an excellent fuel for railroad and manufacturing purposes.

Texas brown coals, therefore, offer a supply of fuel for domestic and industrial purposes equal in all respects to the best of the European, which has come so generally into use. Its nearness to market, the cheapness with which it can be mined, and its near approach in heating value, even in a raw state, to the bituminous coals now in use, make it a most inviting field for development.

CONCLUSION.

In conclusion, I may recapitulate the results of the investigation thus:

Brown coal and lignite of good quality and under proper conditions are fully capable of replacing bituminous coal for any and all household, industrial, and metallurgical purposes, and have proved to be most excellent fuels where properly used.

Texas has an abundant supply of brown coal which is equal to the best quality of that which has been utilized, and far superior to much that is being used satisfactorily in other countries.

The deposits are so situated and of such extent as to permit the mining of these brown coals and their delivery in the various markets of the State at prices far below anything which can be attained with bituminous coals under the most favorable conditions, and the fuel values of the brown coals are such as to enable them, if heating power and price be considered, to compete with any of the bituminous coals which are accessible.

The methods of use which are positively assured for our Texas brown coals are:

The raw coal may be used for all purposes in stoves and grates, under stationary boilers or locomotives, as part fuel in iron smelting, for burning all clay products, cement, lime, etc.

In the form of producer gas it may be used for any and every purpose for which such a gaseous fuel is applicable.

It can be made into illuminating gas and used for lighting and heating.

It can be made into artificial fuel by briquetting with coal tar pitch or some similar agglomerant, and the resulting briquettes will constitute a

fuel which can be used in the same manner, as satisfactorily, and for the same purposes as any ordinary bituminous coal.

Certain varieties of our brown coal will form a coke, if charred, with bond of caking coal and coal tar pitch, which, even if it should not prove sufficiently firm for the blast furnace, will nevertheless answer for fuel for locomotive engines and other similar purposes.

These are the facts. What use shall made of them, and what benefits derived from them, rests with the people of Texas, for whom they have been gathered, and for whose information they are here presented.

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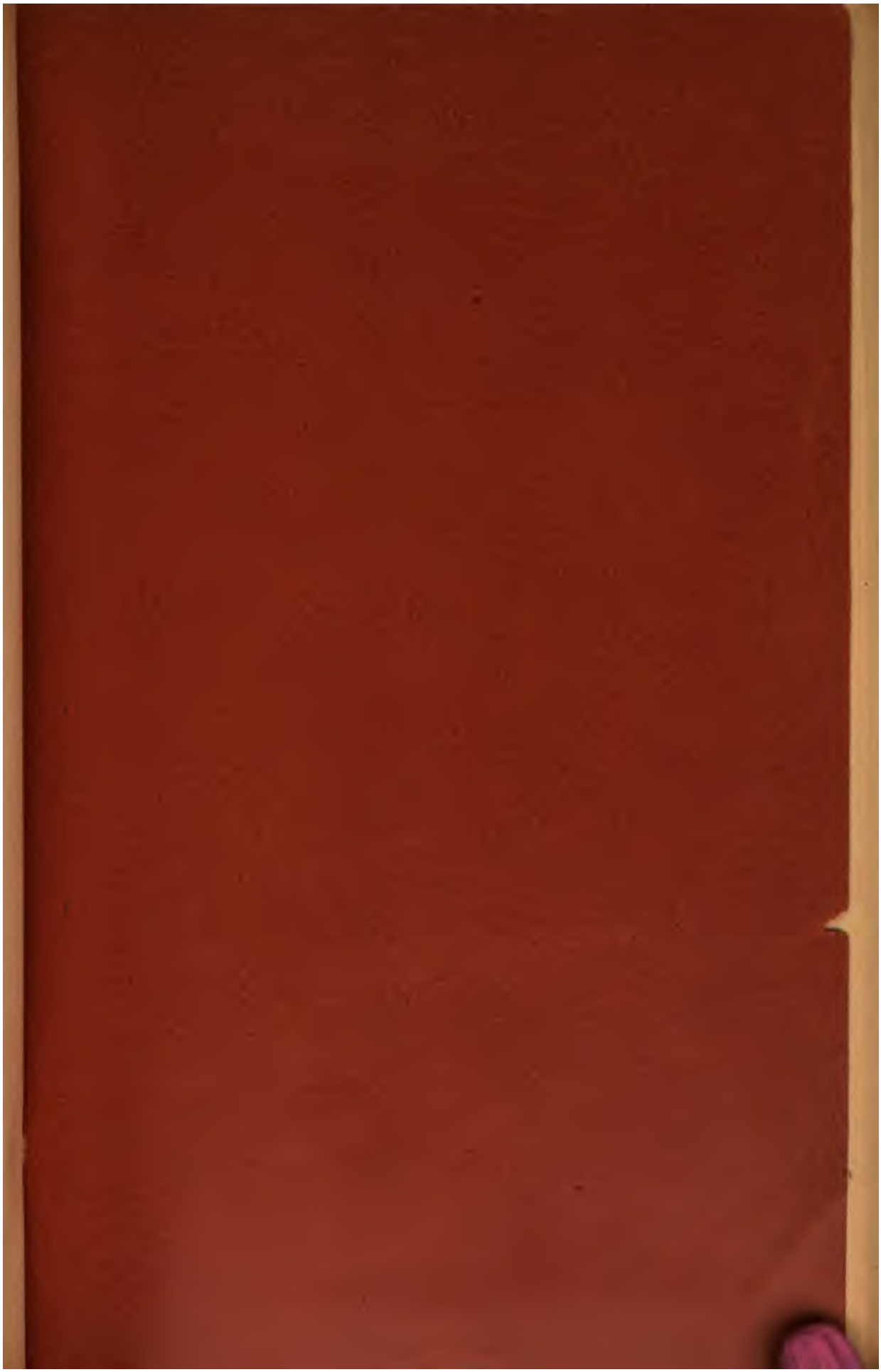

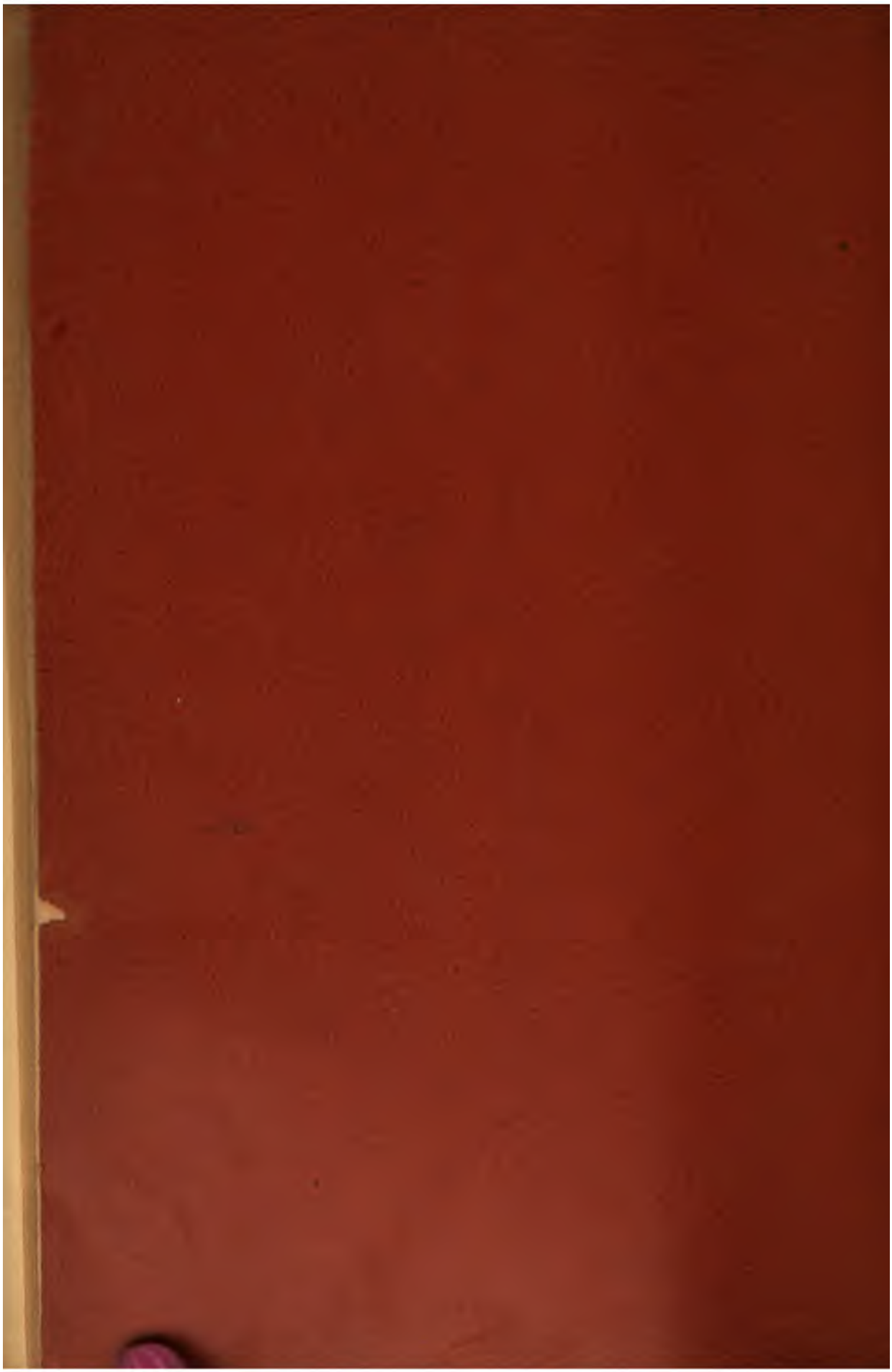

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